FACTORS AFFECTING PRODUCTIVITY AND HABITAT USE OF FLORIDA SANDHILL CRANES (*Grus canadensis pratensis*): AN EVALUATION OF THREE AREAS IN CENTRAL FLORIDA FOR A NONMIGRATORY POPULATION OF WHOOPING CRANES (*Grus americana*)

By

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A crane calling in the shade
Its young answer it.
I have a good goblet.
I will share it with you.
I Ching

This dissertation is dedicated to the memory of 2 friends: Jim Chism (1908-1986), former Curator of Birds at the San Antonio Zoological Gardens and Frank Johnson (1932-1986), former Refuge Manager at Aransas National Wildlife Refuge, Texas.

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EVALUATION OF THREE AREAS IN CENTRAL FLORIDA FOR A NONMIGRATORY
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By

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Three areas in central Florida, identified as potential release sites for a third flock of whooping cranes (Grus americana), were evaluated and ranked as to their priority for reintroduction. Potential reintroduction sites were ranked as follows: (1) Kissimmee Prairie including Three Lakes Wildlife Management Area, Prairie-Lakes State Preserve, and National Audubon Society Kissimmee Prairie Sanctuary; (2) Webb Wildlife Management Area; and (3) Myakka River State Park. Primary criteria used to evaluate each area included the numbers and productivity of breeding Florida sandhill cranes (Grus canadensis pratensis), and the land use status and trends for each potential release site and its surrounding lands. In order to determine the densities of breeding pairs by season and area, systematic aerial transect surveys for nesting Florida sandhill cranes were conducted from March through mid-May for 1984, and mid-January through mid-May during 1985 and 1986. For 1986, surveys indicated the highest densities on the Webb Wildlife Management Area (0.52 pairs/km^2), followed by the Kissimmee Prairie (0.25 pairs/km^2) and Myakka River State Park (0.22 pairs/km^2). Of the three proposed release sites, the two in southwest Florida, Myakka River State Park and Webb Wildlife Management Area, face increasing development pressures surrounding their boundaries. On the Kissimmee Prairie, relative isolation from major population centers and the presence of large, undeveloped family-owned and public landholdings provide optimum conditions for the reintroduction of whooping cranes. On the Kissimmee Prairie, home range and habitat use was determined for 4 paired adults, 2 chicks, and 3 subadult radio-tagged cranes. Average annual home range based on the modified-minimum area method was 1.83 ± 1.03 km^2 (SD) for the paired adults and chicks. Subadults did not maintain a consistent home range area throughout the year. Long distance moves (>5 km) usually were followed by temporary residence in an area. Daytime habitat used most often by monitored cranes was improved pasture (39-78%) followed by herbaceous emergent wetlands (15-47%). Within their home range, Florida sandhill cranes used herbaceous emergent wetlands in greater proportion than their availability.

CHAPTER I
INTRODUCTION

Justification

The Florida sandhill crane (Grus canadensis pratensis) is 1 of 6 subspecies of the sandhill crane and occurs from Okefenokee Swamp in southeastern Georgia to the Florida Everglades. This nonmigratory subspecies is estimated to have approximately 4,000 individuals (Williams 1978, Logan and Nesbitt 1987). The Florida sandhill crane currently is designated as a threatened species by the Florida Game and Fresh Water Fish Commission (FGFWFC) (FGFWFC 1983), indicating that if current trends continue it is likely to become endangered in the State within the foreseeable future (Kale 1978). Although no systematic census or monitoring of the Florida sandhill crane population has been conducted across its range, the loss of habitat through wetland drainage and developments coupled with a low reproductive rate are considered to be the main factors contributing to the low population numbers and a speculated slow population decline (Williams 1978).

Central Florida supports the greatest concentration of Florida sandhill cranes (Walkinshaw 1976). Detailed information, however, is lacking on the populations of cranes throughout this area. There are no total population, breeding pair, or wintering greater sandhill crane (Grus canadensis tabida) estimates for the region.

Before this study began, most of the available information on Florida sandhill cranes in central Florida was from 2 studies of reproductive success. Walkinshaw (1976, 1982, 1987, in press) provided reproductive data for 1967-1987 on Florida sandhill cranes around the Kissimmee Prairie, including Osceola, Polk, and Okeechobee counties. Nest site characteristics, approximate laying dates, and hatch success were determined for over 150 nests. From 1973-1979, Layne (1983) monitored Florida sandhill cranes with young during summer and fall road surveys in south central Florida, primarily Charlotte, DeSoto, Glades, Hardee, Highlands, and Okeechobee counties.

In 1980, the FGFWFC proposed to the Whooping Crane Recovery Team that the nonmigratory Florida sandhill crane be evaluated as a potential foster parent to a third whooping crane (Grus americana) population (FGFWFC 1981). Subsequently, several sites in central Florida were identified for possible whooping crane reintroduction. These sites were initially selected based on the availability of public lands and their estimated populations of Florida sandhill cranes (Nesbitt 1982).

The Whooping Crane Recovery Plan (1986) included, as part of its primary goal, increasing the whooping crane population breeding in Wood Buffalo National Park, Canada, and wintering in Aransas National Wildlife Refuge, Texas, to 40 nesting pairs, and establishing at least 2 additional, disjunct populations each with 25 nesting pairs. The first additional flock of whooping cranes was established in 1975, using greater sandhill cranes nesting at Grays Lake National Wildlife Refuge (NWR), Idaho as foster parents.

In cooperation with the Wildlife Research Bureau of the FGWFWC, I began to evaluate the 3 most promising whooping crane release sites in central Florida in fall 1983. These sites included Myakka River State Park (SP), C.M. Webb Wildlife Management Area (WMA), and the Kissimmee Prairie area, including Three Lakes WMA and the National Audubon Society (NAS) Ordway-Whittell Kissimmee Prairie Sanctuary (Fig. 1-1). This study was designed to complement the FGFWFC investigations on cross-fostering and gentle-release reintroduction techniques being conducted on the Paynes Prairie and Kanapaha Prairie in Alachua County, Florida (Logan and Nesbitt 1987, Nesbitt in press).

In addition to the Florida crane studies, 2 additional potential whooping crane release areas in eastern North America were evaluated during the course of this study. The Ohio Cooperative Fish and Wildlife Research Unit conducted work on greater sandhill cranes at Seney NWR in upper peninsula Michigan and on the wintering grounds in Florida (McMillen 1987). The Georgia Cooperative Fish and Wildlife Research Unit studied the Florida sandhill cranes in Okefenokee Swamp in Georgia (Bennett and Bennett 1987). In February 1988, all 3 studies presented their results and recommendations to the U.S. Whooping Crane Recovery Team in Orlando, Florida.

Objectives

This dissertation is a report of a study conducted in central Florida from September 1983 through January 1987. The overall objectives of this study were the following:

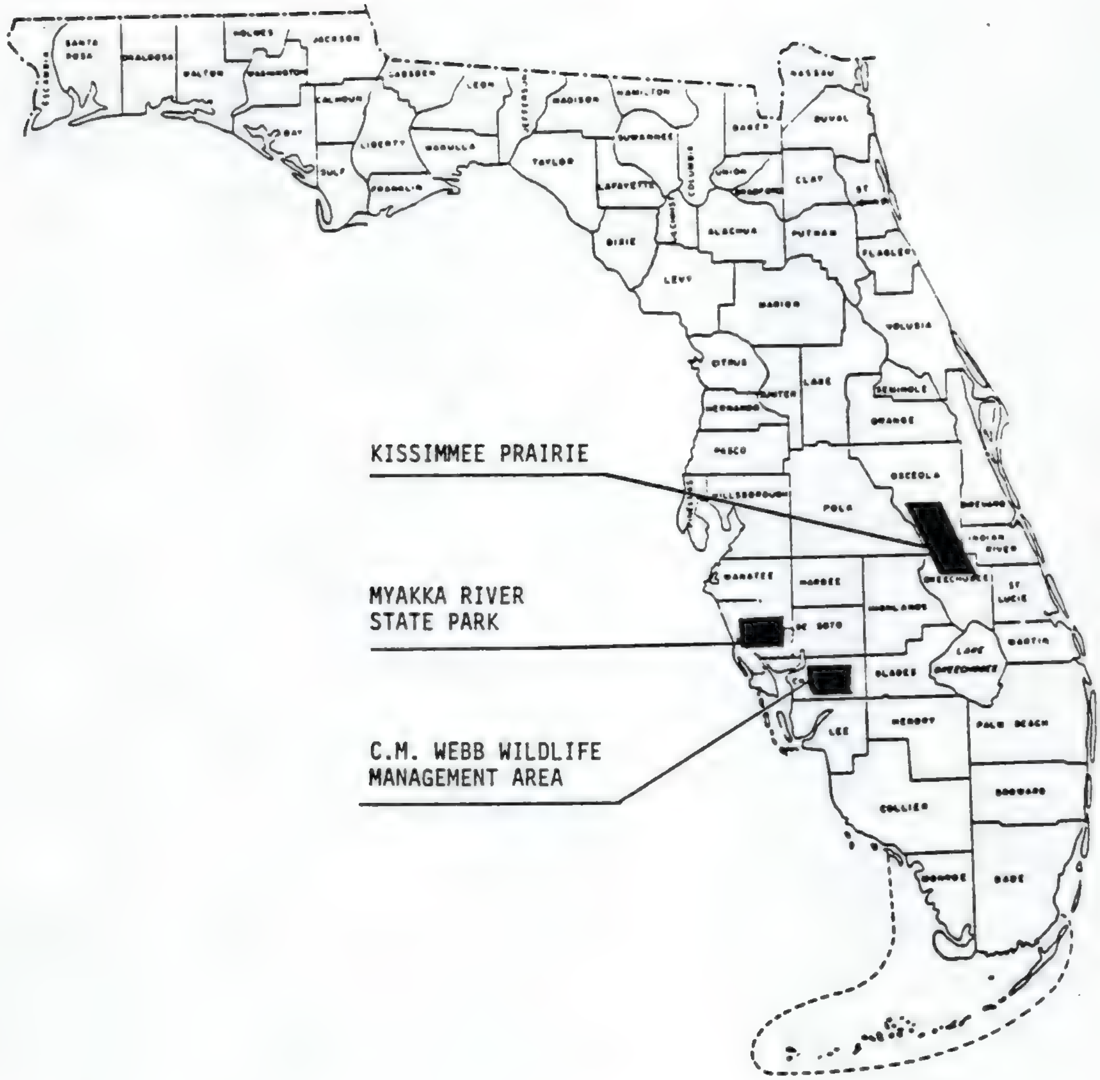

Figure 1-1. Locations of 3 proposed whooping crane release sites in central Florida.

1. Evaluate 3 sites (Kissimmee Prairie, Myakka River State Park, and C.M. Webb Wildlife Management Area) as potential reintroduction sites for whooping cranes.
    a. Characterize the vegetation, land use status and trends for each area.
    b. Estimate the breeding population and annual recruitment of the Florida sandhill cranes.
    c. Determine factors influencing productivity on the 3 sites.
2. Determine habitat use by selected pairs of Florida sandhill cranes residing on the Kissimmee Prairie.
    a. Monitor the seasonal movements and social behavior.
    b. Characterize the habitat and patterns of habitat use within selected cranes' home ranges.

CHAPTER II
LAND USE STATUS AND TRENDS OF POTENTIAL RELEASE SITES

Introduction

Reintroduction, the act of reestablishing an extirpated species, subspecies or ecotype in an area within its original geographic range (Grieg 1979), is a conservation strategy that has been used for several species of animals (Grieg 1979), including Mississippi sandhill cranes (*Grus canadensis pulla*) and whooping cranes (*Grus americana*) (Derrickson and Carpenter 1987). Reintroduction can be a particularly useful strategy to reestablish species whose extinction in a particular habitat were due to factors which have now been controlled (e.g. human persecution, over-collecting, over-harvesting or habitat deterioration) (Int. Union Conserv. Nat. Nat. Resour. 1987). While a reintroduction plan superficially can be an appealing and dramatic conservation strategy, its ultimate success depends on careful planning.

The International Union for the Conservation of Nature and Natural Resources (IUCN) position statement on translocations (IUCN 1987) outlines 4 steps in a reintroduction program. These include an assessment study, a preparation phase, a release or introduction phase, and a follow-up phase. The first step, an assessment study, should include an analysis of factors that influenced the species original decline. The analysis should include an assessment of sociological, scientific, and ecological factors associated with reintroduction.

Land use patterns and trends are important components in assessing current ecological conditions and predicting future scenarios for any potential reintroduction. While public lands can be managed for reintroduction, the surrounding private land use may determine whether the reintroduced population can be sustained or expanded.

In 1980, the FGFWFC proposed to the Whooping Crane Recovery Team that the Florida sandhill crane be evaluated as a potential foster parent to a third, reintroduced whooping crane population. Following preliminary survey work (Nesbitt 1982), in fall 1983 the 3 most promising release sites were selected for further study: Myakka River State Park (SP), C.M. Webb Wildlife Management Area (WMA), and the Kissimmee Prairie area, including Three Lakes WMA and the National Audubon Society (NAS) Ordway-Whittell Kissimmee Prairie Sanctuary (see Fig. 1-1). These sites were initially selected based on the availability of public lands and their estimated populations of Florida sandhill cranes.

As part of an assessment of the suitability of reintroducing whooping cranes in Florida, the objectives of this phase of the study were to (1) characterize the land use patterns and status for the 3 proposed Florida whooping crane reintroduction sites, including surrounding private lands, and (2) evaluate and rank their potential for Florida sandhill crane population expansion as well as whooping crane reintroduction.

Methods

A set of criteria was developed to evaluate land use status and trends for each potential release site and surrounding private lands.

These criteria include acreage, ownership, management, public use, access, potential threats, and the potential to support an expanding population of Florida sandhill cranes and whooping cranes. Operational management plans available for Three Lakes WMA (McCracken 1979), Myakka River SP (Florida Dept. Nat. Resour. (FDNR) 1987), and C.M. Webb WMA (FGFWFC 1982) outlined in most cases land use and vegetation types, as well as the management status and trends for each area. For Three Lakes WMA and Prairie-Lakes State Preserve, vegetation types were digitized using Mark Hurd (1:24,000) aerial photographs and from information provided in the Three Lakes WMA operational management plan and ground truthing. Vegetation types on the Webb WMA were identified from maps prepared by the Florida Department of Transportation (FDOT) (FDOT 1978). Additionally, site managers were interviewed for recent information on access and public usage.

Ownership of private lands were determined from the most recently published plat directories and from county courthouse records. Trends in private land use and potential threats were determined from on-site visits, interviews with local sources, comprehensive regional and county policy plans, estimates of population (Bur. Econ. Business Res. 1987) and from recent Mark Hurd (1:24,000) and county tax assessor (1:4,800) aerial photographs.

Results

C.M. Webb Wildlife Management Area

The Webb Wildlife Management Area contains of 26,454 ha in Charlotte County, Florida and lies in portions of Township 41S Ranges

24 and 25E, Township 42S Ranges 23, 24 and 25E. It is situated 8 km southeast of Punta Gorda, 32 km north of Fort Myers, and 30 km from the Gulf of Mexico. It extends approximately 14.5 km from north to south and 21 km from east to west (Fig. 2-1).

The area is flat and is characterized by poorly-drained sandy soils with either a sandy, organic-stained or a loamy subsoil (U.S. Dept. Agric. 1984). Dominant vegetative communities (Fig. 2-2) consists of 2 similar types: saw-palmetto (*Serenoa repens*) prairies (44%), and pine flatwoods (28%), characterized by South Florida slash pine (*Pinus elliottii* var. *densa*) and an understory of saw-palmetto and wiregrasses (*Aristida* spp.). Freshwater marshes, wet prairies, and intermittent ponds comprise 21% of the land area and are scattered throughout the WMA (FDOT 1978), especially along the south and southwesterly periphery. The most common vegetative cover in the freshwater marshes includes sawgrass (*Cladium jamaicense*). Other characteristic plants include pickerelweed (*Pontederia cordata*), maidencane (*Panicum hemitomon*), arrowhead (*Sagittaria lancifolia*), and spikerushes (*Eleocharis* spp.).

Annual rainfall averages approximately 126 cm on the Webb WMA (U.S. Dept. Commerce 1984). Rainfall is unevenly distributed throughout the year with a dry season from November to April and a wet season from May to October. Over 70% of the rainfall occurs during the wet season. Tropical storms usually occur from August to October and often bring flooding conditions to the area.

The Webb WMA was acquired in 1941 by the FGFWFC for wildlife management purposes. At present, all but 1,063 ha is under the control of the FGFWFC. In the northeast corner, 518 ha have been leased to the

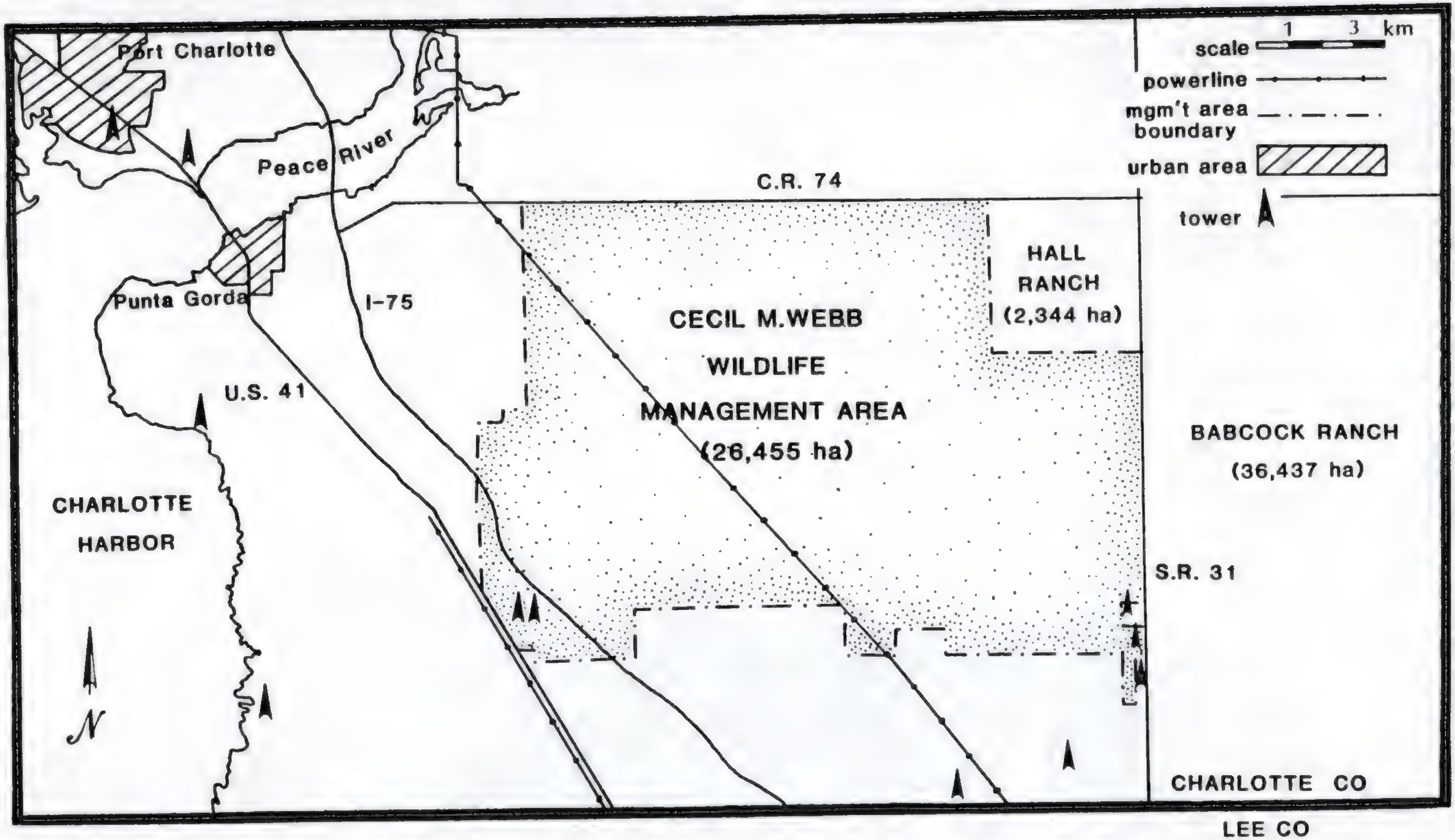

Figure 2-1. Map of C.M. Webb Wildlife Management Area and surrounding lands.

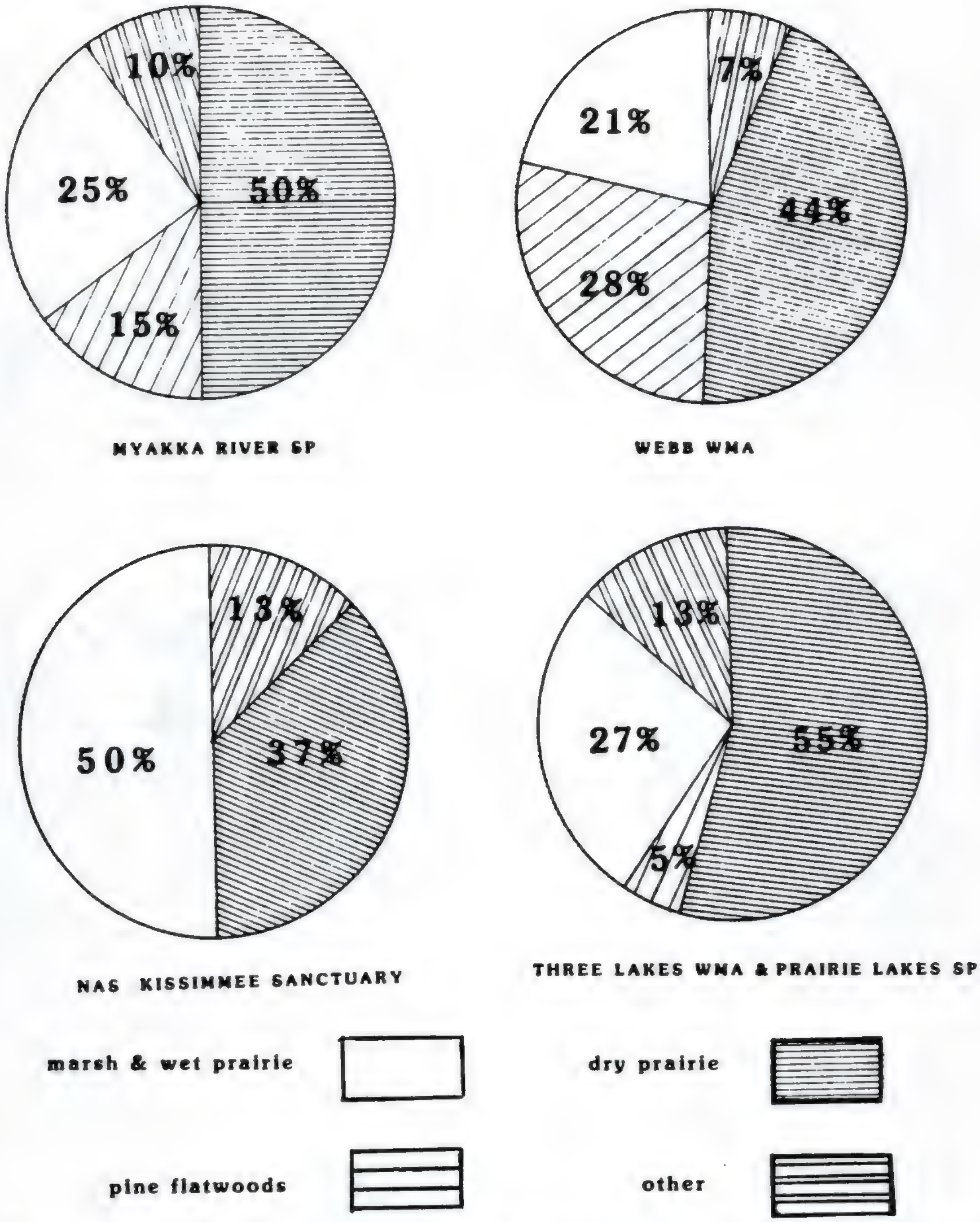

Figure 2-2. Habitat composition for proposed whooping crane release sites in central Florida: Webb Wildlife Management Area (WMA), 26,455 ha; Myakka River State Park (SP), 11,690 ha; National Audubon Society (NAS) Ordway-Whittell Kissimmee Prairie Sanctuary, 2,955 ha; and Three Lakes Wildlife Management Area (WMA) and Prairie-Lakes State Preserve, 11,920 ha, but excluding the 7,150 ha north of the Florida Turnpike.

Boy Scouts of America for a scout camp. In the northwest corner, 358 ha of improved pasture is leased to the City of Punta Gorda for a waste water disposal facility (Appendix A). In the southeast corner, 7 ha is leased as a permanent easement for a television broadcasting tower. Additionally, there are 18 in-holdings, accounting for 180 ha.

The current operational management plan (FGFWFC 1982) proposes that 2 tracts on the Webb WMA be leased or sold for commercial value. These include 463 ha between US 41 and I-75, and 10 ha lying within the I-75 interchange at Tuckers Grade (Appendix A).

Since its acquisition as a state wildlife management area, the primary management emphasis has been on bobwhite quail (*Colinus virginianus floridanus*) through habitat manipulation. Quail feeders have been used to supplement natural food supplies and are frequently used by the Florida sandhill cranes. As part of a 5 year study on quail, 350 feeders are serviced year-round (L. Campbell, FGFWFC, pers. commun., 1987).

Prescribed burning and cattle grazing have been the major management tools to maintain ground vegetation in early succession. Semi-annual burning of 65-ha blocks of pine flatwoods and saw-palmetto prairies is conducted between November and the first week in March. Cattle are grazed by lease agreement with private individuals on all but 3,100 ha reserved for bird dog field trials (FGFWFC 1982). There are two 6,480-ha pastures with 1 and 4 cross fences, respectively, and one 4450-ha pasture with 1 cross fence. All interior fences are 4-strand barbed wire (L. Campbell, pers. commun., 1987).

In recent years, historic sheetflow patterns have been altered as a result of the dikes and roads associated with peripheral ranchette type developments. Sheetflow has become concentrated toward culvert outlets, bridges, and creeks. On the west side of the Webb WMA, drainage has been accelerated, whereas on the south side, flooding is caused by dikes on private property (FGFWFC 1982, Johnson Engineering Inc. 1983).

In 1983, a water management plan for the Webb WMA (Johnson Engineering Inc. 1983) included proposed water control structures to alleviate the seasonal extremes in the hydroperiod and the uneven peripheral outflow. Since then water control structures have been installed at 11 locations on the management area. These structures allow surface water flow to be directed into specific wetland areas and at the same time create upstream impoundment areas. Another 5-7 structures will be installed in the future as part of the hydrological plan (L. Campbell, pers. commun., 1987).

In 1987 an agreement was reached between the Department of Corrections and the FGFWFC to install 5 or 6 shallow production wells as a potable supply source for a new correctional facility 2.5 km south of the WMA. Plans are underway to monitor the effect of these withdrawals on water levels and the existing vegetative habitat.

Currently, 4,450 ha on the west side of the Webb WMA is open year-round for vehicle access and recreation during daylight hours (Appendix A). The primary non-hunting recreational activities have been fishing and frogging and use of the shooting range. Non-hunting man-day use in 1986 totaled approximately 25,000 per year (L. Campbell, pers. commun., 1987).

The hunting season on the Webb WMA begins at the end of October with a 9-day deer and hog hunt. Typically quail and small game hunting is permitted from November 14 through mid-February. Although there have been attempts to improve waterfowl habitat on the Webb WMA, waterfowl hunting is virtually nonexistent. Instead, most waterfowl hunting occurs in Charlotte Harbor (Fig. 2-1), west of the WMA. With the exception of the deer and hog hunt, and the first 6 days of the quail season, hunting is allowed only Wednesday, Thursday, Saturday, and Sunday. During the 1986-87 hunting season, approximately 4,288 people participated in management area hunts. Vehicles are allowed throughout the Webb WMA during the hunting season with the exception of 2 walk-in areas on the north and south end (Appendix A).

The perimeter of the Webb WMA is fenced with woven "hog" wire. Public access to the Webb WMA is controlled through the Tucker Grade entrance. Two exceptions are the "40-acre pond" on the north side which is open during the non-hunting season, and the bird dog field trial grounds (Appendix A) which are open from October through the end of January. Three-wheeled vehicles and motorcyles are prohibited from all parts of the Webb WMA.

Webb Wildlife Management Area Surrounding Land Use and Potential Threats

Contiguous to the Webb WMA on the east side are 2 large private landholdings (Fig. 2-1) that are managed for timber, cattle, and wildlife. Telegraph Swamp, an extensive cypress (*Taxodium distichum*) swamp, cuts through both of these properties. The 2,343-ha Hall Ranch to the northeast is family-owned and operated. The large 36,450-ha Babcock Ranch to the east extends to the county line and south into Lee County. This ranch is incorporated but is owned by one family. Both the Hall and Babcock ranches lease hunting rights to private individuals. Nesting Florida sandhill cranes have been observed on both of these areas.

On the southwest side of the Webb WMA there are still some 7 undeveloped parcels ranging in size from 259 ha (1 section) to 1,495 ha, including 2 that adjoin the Webb WMA. Cranes are known to nest or use at least 4 of these parcels on a regular basis. Given the proximity to I-75, US 41, and Ft. Myers, as well as the construction of a new county jail in the area, development will probably continue into the future.

While not contiguous, there are 2 other large inland landholdings within 37 km of the Webb WMA that support crane populations. These include the approximately 121,450-ha family-owned and operated Lykes Brothers Fisheating Creek Ranch, 19 km to the northeast and Myakka River SP-Sarasota County Ringling-MacArthur Reserve, approximately 37 km to the northwest (Fig. 1-1).

To the north, south, and west the Webb WMA is surrounded by platted developed and undeveloped lands and small (2-4 ha) tracts. These developments are the result of both a significant population growth on and near the southwest coast of Florida since 1950 and accompanying land speculation. Between 1980 and 1986, human populations in Charlotte and the adjoining Lee and Sarasota counties increased by 42%, 35%, and 21%, respectively (Table 2-1) (Bur. Econ. Business Res. 1987). While these populations are expected to continue growing, the growth rates seen in the past will likely not be as great (Southwest Florida Reg. Planning Counc. 1987).

Large, platted, undeveloped lands that have minimum street and drainage facilities are concentrated in the cities of Cape Coral in Lee

Table 2-1. Human population growth and forecasts by county for selected areas in central Florida.

County	1980[a]	1986[a]	1990[a,b]	2000[a,b]
Charlotte	58,460	82,968	104,600	155,000
Lee	205,266	277,375	344,000	494,700
Manatee	148,445	175,893	201,500	256,000
Sarasota	202,251	244,634	286,600	382,700
DeSoto	19,039	22,287	26,100	33,800
Okeechobee	20,264	26,564	32,200	43,800
Osceola	49,287	82,554	111,900	174,900

[a] Bureau of Economic and Business Research, 1987.
[b] Estimates based on high human growth projections similar to large migration levels of 1970-1975.

County, North Port in Sarasota County, and in unincorporated coastal areas of Lee and Charlotte counties. Although large-scale speculation has slowed considerably since the 1960's, large development projects continue to be approved. In 1987 Charlotte County approved the 728-ha Seminole Trail development for 5,600 people. This development is contiguous to the north side of Webb WMA, across from the "40-acre pond" (Appendix A) (L. Campbell, pers. commun., 1987).

Development for agricultural purposes is increasing as well as for human populations. As a result of 4 winter freezes between 1983 and 1986 which damaged or killed groves in central Florida, citrus production is shifting to southwest Florida at a significant rate. Most of this increase, however, is occurring to the east and south of Charlotte County. In Charlotte County, citrus production is concentrated north of CR 74. As of 1986, approximately 3,550 ha were in commercial groves (Florida Crop Livestock Rep. Serv. 1986).

In addition to development pressures and increased conversion to citrus groves, there are 2 other potential threats to cranes in this area: aerial hazards and tropical storms. Three north-south electrical transmission lines cut through the study area, (Fig. 2-1), including 2 adjacent 230 kV lines that diagonally cross the Webb WMA, and another 230 kV line that runs along US 41. Additionally, there are electrical distribution lines, especially in the adjoining and nearby developed areas. Broadcasting towers also exist in the area, including 3 television towers located in the southeast corner and 2 smaller towers in the southwest corner of the WMA (Fig. 2-1).

Southwest Florida has been identified by the National Weather Service as one of the most hurricane-vulnerable areas of the United

States. Ft. Myers, 32 km to the south of the WMA, has a probability of hurricane-force winds (>119 km/h) occurring every 12 years (Fernald and Patton 1985). Although the Webb WMA lies at least 30 km from the Gulf of Mexico, high winds and water that accompany hurricanes could endanger and/or displace cranes.

Myakka River State Park

Myakka River State Park is Florida's largest state park and contains 11,690 ha in Manatee and Sarasota counties (Fig. 2-3), including portions in Township 37S Ranges 20, 21E, Township 38S, Ranges 20, 21, 22E, and Township 39S Range 22E. The park is situated 27 km east of Sarasota, 48 km southeast of Bradenton, and 17 km from the Gulf of Mexico.

Similar to the Webb WMA, Myakka River SP is relatively flat and is characterized by poorly-drained sandy soils with either sandy, dark-colored or loamy subsoils (U.S. Dept. Agric. 1983). Dominant vegetation communities (Fig. 2-2) are broad saw-palmetto prairie (>50%), and slash pine flatwoods (15%). Freshwater marshes, wet prairies, and sloughs comprise approximately 25% of the land. The Myakka River flows through the park for 13 km, and forms the western boundary throughout most of the park (Fig. 2-3). Major marshes are found primarily along the river and its 2 large lakes, Upper and Lower Myakka (FDNR 1987).

Annual rainfall averages approximately 144 cm on Myakka River SP (U.S. Dept. Commerce 1984). Between 70-80% of the rainfall occurs during the wet season (May-October), and much of the park is flooded

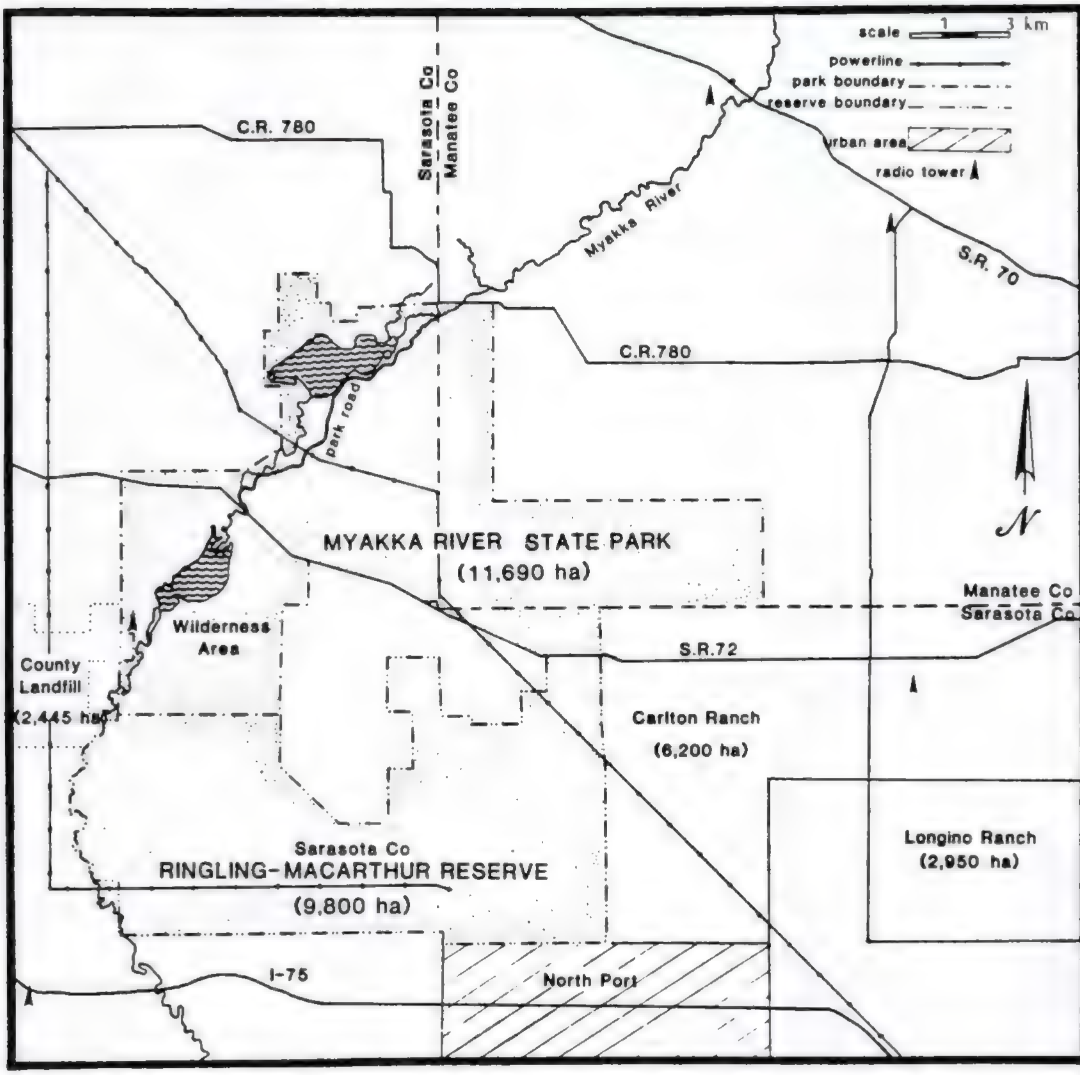

Figure 2-3. Map of Myakka River State Park and surrounding lands.

during these months. Like the Webb WMA, tropical storms usually occur in the months of August through October.

Myakka River SP was initially opened to the public in 1941. The main goal of the park is to preserve and maintain a natural setting while permitting a full program of compatible recreational activities, both active and passive. It is the philosophy and policy of the Florida Park Service to manage all state parks as closely as possible to their appearance when the first Europeans arrived. Consumptive uses, therefore, including hunting, livestock grazing, and timber removal are not permitted (FDNR 1987).

There are 2 major management zones in the park: development and natural. The development zone includes an interpretive center, a food and boat concession on Upper Myakka Lake, a tram tour, campgrounds, and cabins. These facilities are all located on the north side of SR 72, and are confined to a small corridor along Myakka River and Upper Myakka Lake.

The natural management zone includes 3 areas: a wilderness preserve, river zone, and all other natural areas of the park. The wilderness preserve is the 3,036-ha area south of SR 72 (Fig. 2-3). This area is managed in the same manner as the non-river natural zone; however, visitation is restricted to 30 persons per day on foot and 12 canoes per day. The river zone includes Myakka River, Upper Myakka Lake, and Lower Myakka Lake. Water levels and precipitation are monitored for this area. Water management emphasizes the treatment and control of exotic wetland invaders, in particular, *Hydrilla verticillata*.

The non-river natural area and the wilderness preserve both are monitored and managed to resemble as closely as possible "original natural Florida." From 1934-1970 natural fires were suppressed and controlled burning was not allowed within the park. During these years there was an accumulation of woody species in historically herbaceous areas.

Beginning in 1971, controlled burning was used to recreate the "original natural Florida" in the non-river natural area. Fire-dependent communities, such as the dry saw-palmetto prairie, the flatwoods, and marshes are now typically burned at 1-4 year intervals, depending on their successional state. Late-spring and summer burns are prescribed for flatwoods and saw-palmetto prairie to approximate natural lightning-set fires. Freshwater marsh, such as those along the river, are burned in late winter and early spring (FDNR 1987).

Habitat destruction by feral hogs (Sus scrofa) has become a management problem on Myakka River SP. The overpopulation of hogs is due to both the absence of natural predators and a lack of hunting pressure. Beginning in May 1986, a trapper was contracted to remove hogs from the park using traps and dogs. During the first year, 668 hogs were removed and a 1200-hog limit was set for 1987 (Myakka River SP files).

Short-term flooding along the river and the Upper and Lower Lakes is the major hydrological management problem within the park. The 2 existing subdivisions on the northwest side of the park direct their drainage into Myakka River causing a rapid rise in river and lake levels following heavy precipitation. The diking of both Tatum Sawgrass, a 1,740-ha marshy depression adjacent to the north of the park, and Vanderipe Slough just south of Upper Myakka Lake also has changed the historical hydroperiod in the marshes and lowlands adjacent to the lakes and river. The change in hydroperiod has permitted hardwoods, primarily Carolina ash (*Fraxinus caroliniana*) to invade marshes and has increased the hammocks that border the river zone (FDNR 1987).

In other parts of the park, sheet flow has been impeded by SR 72 and all-weather roads built to permit park and utility line personnel access during the wet season. At the same time, some fire lines serve as artificial channels and hasten drainage from other areas. Fire lines tend to hold water on the sites and will sometimes impede control burns. Currently, these fire lines are being allowed to become overgrown to alleviate the problem (FDNR 1987).

Myakka River SP is open year-round to the public. During FY 1987, there were 254,066 visitors, 20% of whom are from states other than Florida. Vehicular access to Myakka River State Park is primarily through one entrance on SR 72. On weekends, a north entrance on CR 780 is open. Within the park, there is a north-south road open to the public. With the exception of 60 km of backpacking trails, 25 km of horseback riding trails, and the wilderness preserve on the south side of SR 72, all recreational activities (picnicking, camping, fishing, boating, bicycling, and cabins) are concentrated along this one road.

Myakka River State Park Surrounding Land Use and Potential Threats

Immediately bordering the park to the south and portions of the west are large tracts of undeveloped and ranchlands. In 1984, 6,500 ha of the 13,200-ha Ringling-MacArthur tract was purchased by the County of Sarasota as a potable water supply source and additionally as a recreation and open space area (Sarasota County Ordinance No. 82-94). These lands were subsequently designated the Sarasota County Ringling-MacArthur Reserve. Currently, there are negotiations to purchase an additional 3,300 ha for a total of 9,800 ha in the reserve (Fig. 2-3) (J. Lincer, Sarasota County, pers. commun., 1988). The original 13,200-ha tract is primarily pine flatwoods (42%), saw-palmetto prairie (16%), and wetlands (29%) (Lincer 1982).

Management on the Sarasota County Ringling-MacArthur Reserve will be primarily for water, recreation, and wildlife, and must be compatible with the management on Myakka River SP (Sarasota County Resolution No. 82-200). There is a long-term monitoring program of the surficial and subterranean water regimes aimed at assessing the impacts on and preserving the integrity of the wetlands on the tract. A significant percentage of the reserve will be designated in the preservation category to protect the flora, wildlife, and wetlands from any unnatural changes. The interim burning plan is similar to Myakka River SP, and focuses on May and June controlled burns. Recreation uses considered priority are those that are resource-based, nonconsumptive, and ecologically benign, with a special emphasis on environmental education. Currently the reserve is closed to the public. It will not be open until support facilities, including a main access road, are constructed (J. Lincer, pers. commun, 1987).

North of the Ringling-MacArthur Reserve, the remaining 3,240 ha of the original Ringling-MacArthur tract continues to be owned by a private foundation (Fig. 2-3). Through an agreement with Sarasota County, all of the development rights are suspended on this portion until 1994, and the county permanently retains all rights to intermediate and deep waters, but not surficial water. The foundation leases hunting and grazing rights to a private sporting club (J. Lincer, pers. commun., 1987).

Adjoining both the Ringling-MacArthur Reserve and Myakka River SP to the southeast and southwest are family-owned and operated ranches managed primarily for cattle with some timber and citrus production. Large portions of these lands were cleared several years ago for improved pasture. A 2,445-ha ranch to the southwest of the park was recently purchased by Sarasota County for a landfill (Fig. 2-3). Only a small portion of the parcel will be used at one time for a landfill; and the rest of the property will be left as is (R. Klier, Sarasota County, pers. commun., 1987).

Along the irregularly-shaped northeast border of the park, small (<800 ha) ranch operations are most common. Recently, however, a 850-ha parcel adjoining the park was platted for ranchettes. To the north and northwest, small tracts and 2 established subdivisions also border the park.

Like the other coastal counties in southwest Florida, Sarasota has and will continue to experience a relatively high growth rate (Table 2-1). Currently the policy of Sarasota County is to contain high-density development to the west of I-75 (Sarasota County 1981). Two and 4-ha tract developments, however, are allowed in rural-zoned areas and are a growing trend along CR 780 and other areas east of I-75 interchanges. Already bordering a portion of the Ringling-MacArthur Reserve is North Port, a sparsely settled community that includes 81,700 undeveloped lots and 1.2-ha tracts (Fig. 2-3). While its population, including winter residents, is estimated at only 13,000 people, over 38,000 people are predicted by the year 2000 (Bur. Econ. Business Res. 1987).

Aside from development pressures in rural areas near Sarasota, another environmental threat in this area is the phosphate industry. Seven phosphate companies own large landholdings in eastern Manatee County for future mining. Thus far, these lands are used primarily for agriculture (Manatee County 1986). If phosphate mining is initiated in this area, it would not only eliminate wetland habitat, but could have negative effects on the Myakka River watershed (FDNR 1987).

Two other potential threats to cranes in this study area are aerial hazards and hurricanes. Aerial hazards include 4 electrical transmission lines both near and in the park (Fig. 2-3). Two adjacent 138 kV and 230 kV lines cut diagonally across the park and into the Ringling-MacArthur Reserve. The other 2 transmission lines include an 230 kV east-west line along the south end of the Ringling-MacArthur Reserve, and a 230 kV north-south line that runs west of the park. There are relatively few transmitting towers in the area (Fig. 2-3). The westernmost part of Myakka River SP lies 17 km from the Gulf of Mexico. As with the Webb WMA, a hurricane could cause substantial flooding in the area and displace cranes.

Three Lakes Wildlife Management Area

Three Lakes Wildlife Management Area consists of approximately 19,100 ha in south central Osceola County and includes portions of Township 29S Ranges 32 and 33E, Township 30S Ranges 31 and 32E, Township 31S Ranges 31 and 32E. It is situated approximately 40 km from St. Cloud and over 55 km from the Atlantic Ocean. Three Lakes WMA borders Lakes Jackson, Marian, and Kissimmee. The Florida Turnpike and CR 523 divide the property into 3, approximately equal, parts. Prairie-Lakes State Preserve also divides the area (Figs. 2-4, Appendix B). Of the total acreage, approximately 7,150 ha lie north of the Florida Turnpike, and approximately 12,000 ha lie south of the Turnpike.

Three Lakes WMA is flat and is characterized by poorly drained sandy soils. Dominant vegetation cover on the 7,150-ha area north of the Florida turnpike includes cypress (*Taxodium* spp.) strand swamps and domes (19%) and slash (*Pinus elliottii*) and longleaf pine (*Pinus palustris*) flatwoods (72%). Suitable crane habitat on Three Lakes WMA lies primarily south of the Turnpike, where broad saw-palmetto prairie (55%) and wet prairie and freshwater wetlands (29%) provide the major vegetative cover for this 12,000-ha area (Fig. 2-2). Long-term rainfall for Three Lakes WMA averages 131 cm per year (South Florida Water Manage. District files). Between 70-80% of the rainfall occurs during the wet season (May through October).

Three Lakes WMA was purchased by the State of Florida in 1974 under the Environmentally Endangered Lands Program. The major objective of the purchase was to preserve and protect the area and its endangered or threatened fauna and flora for the present and future benefit of Floridians. Management responsibility for the original purchase was divided between the FGFWFC (Three Lakes WMA) and the FDNR (Prairie-Lakes State Preserve). The management policy of the FGFWFC for Three Lakes WMA is to protect and enhance the land, wildlife, and fisheries values, and to manage the land for compatible outdoor

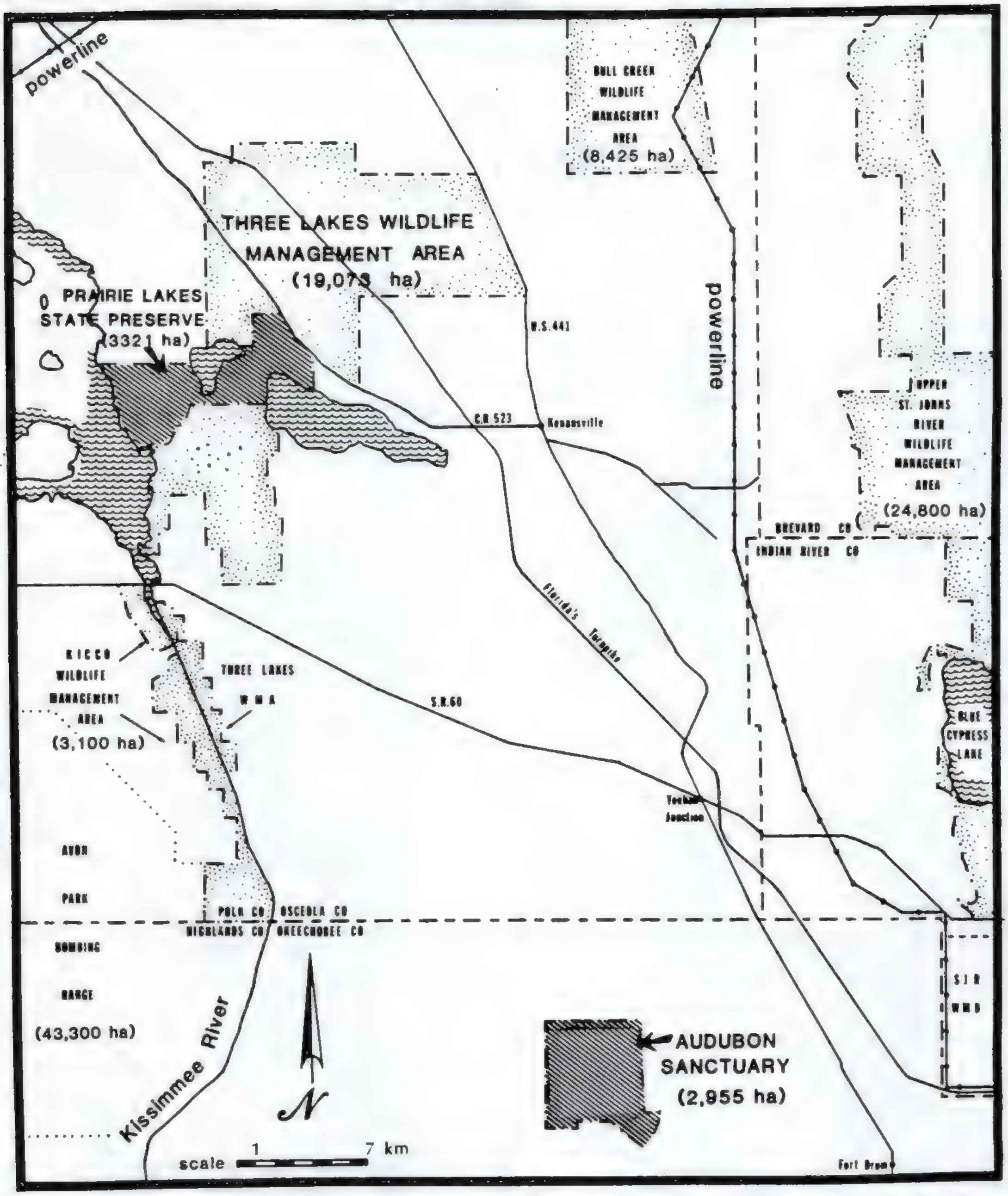

Figure 2-4. Map of Kissimmee Prairie study area including Three Lakes Wildlife Management Area, Prairie-Lakes State Preserve and National Audubon Society Ordway-Whittell Kissimmee Prairie Sanctuary. All Florida Game and Fresh Water Fish Commission Wildlife Management Areas are stippled.

recreational activities (McCracken 1979). Total acreage on Three Lakes WMA was increased in 1986 when FGFWFC acquired from the U.S. Federal Government an additional 780 ha along the extreme northeast WMA border. The Federal Government retained ownership on 750 ha of adjacent lands.

In 1986, the Florida Natural Areas Inventory submitted a proposal to the State of Florida's Conservation and Recreation Lands Program (C.A.R.L.) for the acquisition of approximately 22,400 ha as an addition to Three Lakes WMA and Prairie-Lakes State Preserve (Appendix B). Since then the proposal and a project design for 20,800 ha have been reviewed and approved by the C.A.R.L. Committee. At the June 1988 C.A.R.L. meeting, the Three Lakes WMA/Prairie-Lakes State Preserve addition was ranked 23rd on the C.A.R.L. acquisition list for 1988. The timing of acquisition will now depend on both this ranking and the availability of funds.

The proposed Three Lakes WMA/Prairie-Lakes State Preserve Addition represents the most extensive less-than-fee-simple acquisition procedure ever used in a C.A.R.L. project design. Only 890 ha of the 20,800 ha are being recommended for fee-simple acquisition. These include the private lands bordering Lake Jackson and the north side of Lake Marian. Conservation easements or owner contract agreements are being recommended for the 2 largest parcels: the 4,000-ha Lucky L Ranch, north of CR 523, and the 12,100-ha Adams Ranch, south of Lake Marian to SR60. Access easements, drainage easements, and conservation easements are recommended for the remaining private lands (FDNR 1988).

Predominant natural communities on the proposed addition are dry saw palmetto prairie, mesic flatwoods and prairie hammock. Much of the land has been altered for grazing purposes. The principal reason for the proposed addition is to assure increased protection for native wildlife species, particularly birds such as sandhill cranes and bald eagles (*Haliaeetus leucocephalus*) that require extensive areas of habitat to maintain viable populations (Jackson 1986).

Management on Three Lakes Wildlife Management Area

Until recently, cattle grazing and controlled winter burns on a 3-year rotation were the major management tools for maintaining the dry and wet prairies and the pine flatwoods habitats on Three Lakes WMA. Cattle grazing was discontinued indefinitely in 1986 on all but the Kissimmee River portion. State smoke management regulations requiring early "fire out" times, coupled with a shortened burn season due to conflicts with the hunting season, have resulted in fewer hectares burned per year than scheduled. In September 1987, a new experimental burn program was implemented using faster, helicopter-initiated fires.

Prior to its acquisition by the State, significant ditching and canal work was done on Three Lakes WMA and the surrounding areas to provide improved grazing land for cattle and for flood control. The primary result of the modified drainage has been a shortened hydroperiod. A hydrological plan to restore some of the historical water regime has been written for Three Lakes WMA (McElroy 1977); to date, however, there has been no money appropriated to implement the plan.

Currently, Three Lakes WMA is open year-round to the public. The primary recreational activity has been hunting with deer, small game, and spring turkey seasons spanning the months of October through mid-April. Deer hunting, the most popular sport, supported almost 16,000 man-days in 1986. There is a minimum of waterfowl hunting on Lake Jackson in Three Lakes WMA. While estimates of man-days are not available, waterfowl hunting on Lake Kissimmee is popular during the 45-day season (F. Johnson, FGFWFC, pers. commun., 1988).

The perimeter of Three Lakes WMA is fenced with a 4-strand fence. Public access to Three Lakes WMA is limited to 3 roads: 1 for each major section (Appendix B). The 700-ha portion of Three Lakes WMA along the Kissimmee River (Fig. 2-4) has no public access. Except during the small game season, vehicles are permitted only on named or numbered roads. Public camping facilities have not been developed on Three Lakes WMA, and primitive camping is allowed in designated areas only during the hunting season.

Prairie-Lakes State Preserve

Prairie-Lakes State Preserve lies between the northern and southern portions of Three Lakes WMA (Figs. 2-4, Appendix B). In keeping with the FDNR policy mentioned earlier for Myakka River SP, this 3,300-ha preserve is managed to resemble its appearance when the Europeans first arrived. Consumptive uses, including hunting, livestock grazing and timber removal, are not permitted.

The 3 primary habitat types on the Preserve are dry prairie (65%), freshwater marsh (11%) and upland hardwoods (16%) (Fig. 2-2). Prescribed burning on a 1-3 year rotation is the primary management strategy for preserving the freshwater marsh and dry prairie communities. Similar to Three Lakes WMA, Prairie-Lakes State Preserve has suffered from insufficient burning because of logistical problems, resulting in rank vegetation in many areas. From 1983 through 1985, an average of only 214 ha was burned per year. In November 1986, an arson-instigated fire burned almost 900 ha in the area west of Lake Jackson. Previous to this incident, this area had not been burned in almost 7 years (Prairie-Lakes State Preserve files).

Prairie-Lakes State Preserve is open to the public year-round during daylight hours. Fishing on Lake Jackson is the major recreational use; hiking, nature study, and picnicking are also permitted. There are no developed camping facilities. Public use of Prairie-Lakes State Preserve has been relatively low. For FY 1985-1986 and 1986-1987, an estimated 6,079 and 3,872 people, respectively, used the Preserve (Prairie-Lakes State Preserve files). Public access is confined to one road running through the eastern portion of the Preserve, from CR 523 to Lake Jackson. The western portion of the Preserve has been designated a wilderness preserve. No vehicular access by the public is allowed in this area (S. Graf, FDNR, pers. commun., 1988)

National Audubon Society Kissimmee Prairie Sanctuary

Located in Okeechobee County approximately 10 km southeast from the southernmost portion of Three Lakes WMA, the National Audubon Society's Ordway-Whittell Kissimmee Prairie Sanctuary comprises approximately 2,955 ha (Fig. 2-4). An initial purchase of 2,330 ha was completed in 1980, and since then 624 ha along the southern end has been acquired.

The sanctuary is located at the head of one of the Kissimmee tributary watersheds (Seven Mile Slough) in an area where there has been little water management activity. Water regimes on the site are still quite natural and the area is generally wetter than other parts of the prairie. Over 50% of the property is wet prairie or freshwater marsh; another 37% is dry prairie (Fig. 2-2) (NAS files).

The primary purpose of the Kissimmee Prairie Sanctuary is the preservation of natural areas and their associated wildlife species. Public education and research also are management goals for the Sanctuary, although both have been on a small scale. Prescribed winter burns have been the management tool used to maintain the prairie community. Cattle grazing is not permitted on the Sanctuary.

The Sanctuary is open to the public by appointment only. There are no public roads accessing the property. In the long-term, there are plans to build a visitor's center on the property and upgrade existing roads for public access.

Surrounding Lands and Potential Threats to Three Lakes WMA/Prairie-Lakes State Preserve and Kissimmee Prairie Sanctuary

The majority of the study area includes large (>2,700 ha) family-owned and operated ranches (Table 2-2). Four of the largest ranches in the area share borders with Three Lakes WMA: Adams Ranch (12,100 ha), Latt-Maxcy (42,500+ ha), Bronson (3,100 ha), and Lucky L (4,000 ha). Private ranches are managed for cattle, sod farming, and wildlife. Citrus is of minor importance in the area, as the land is generally too low to be considered prime citrus land. Much of the native rangeland was converted to improved pasture since the 1960's. In Okeechobee County for example, 20% (16,200 ha) of approximately 81,000 ha of native rangeland was converted to improved pasture between 1960-1969. During 1970-1979, an additional 14,200 ha was converted to improved pasture (Okeechobee County Soil Conserv. Serv. files). Since then, low

Table 2-2. Approximate size (ha) of large private and public landholdings on and near the Kissimmee Prairie, Florida. Starred ranches border Three Lakes Wildlife Management Area.

Private Ranches	Size
Adams Lake Marian*	12,100
Latt-Maxcy El Maximo*	42,500
Bronson	
Three Lakes*	3,100
Kenansville	5,600
Lucky L*	4,000
Overstreet*	2,700
Campbell Escape	2,800
Leroy Bass	5,600
Hayman 711	3,800
Public Lands	
Three Lakes WMA	19,073
Prairie-Lakes SP	3,300
NAS Kissimmee Prairie Sanctuary	2,955
Kicco WMA	3,100
Bull Creek WMA	8,425
Upper St. Johns River WMA	24,800
Avon Park Bombing Range	43,300
Total Public Lands	104,953

beef prices and the increased housing demand in other parts of Florida has made sod-farming of pastureland an increasingly important economic activity and has increased conversion pressures on the remaining native habitat.

Wildlife is an important economic activity for the private ranches that lease hunting rights to private individuals and clubs. Currently, however, many of the larger ranch owners (Adams, Latt-Maxcy, Campbell, and Leroy Bass) only allow family and friends to hunt on their properties. Most ranch owners take an active interest in wildlife, often planting food plots and maintaining feeders for quail, turkey, and deer.

Large areas in and around the study site are public lands (Fig. 2-4). On the east side of the study area, the St. Johns River Water Management District (SJRWMD) is a major landholder, both along and near the St. Johns River. With monies from the "Save Our Rivers Act", the District has recently acquired 9,000 ha in the river floodplain immediately north of SR 60, and 6,000 ha of Ft. Drum Swamp to the south as part of a restoration program. These lands form the headwaters of the St. Johns River and were once a broad, expansive marsh. Over the years, thousands of hectares within the floodplain were converted to agriculture through extensive systems of canals and levees.

The majority of the public lands in this portion of the St. Johns River have been designated as 3 marsh conservation areas. Their purpose is for water conservation and temporary storage of stormwater before being discharged into adjacent stormwater storage areas. Over the next 5 years, agricultural lands currently used for pasture and row crops will be reflooded, and in some areas, should become a herbaceous or shrubby marsh (SJRWMD 1983, 1987).

While water management is the primary purpose of the public lands held by the District, secondary purposes include the protection and improvement of fish and wildlife values and public recreation (Houder 1987). Currently, a continuous 30 km stretch along the St. Johns River and floodplain between SR 60 and US 192 are managed through an agreement with the FGFWFC as the 24,800-ha Upper St. Johns River Marsh Type II Wildlife Management Area (Fig. 2-4). The Type II designation means that all management activities, including hunting permits, are handled through the Water Management District.

Access to the Upper St. Johns WMA is almost exclusively by boat. The area is open year-round for fishing and frogging. Hunting season is generally October through mid-April and includes deer, small game, and spring turkey hunts; no trapping is allowed.

Northeast of Three Lakes WMA, the Bull Creek WMA is also owned by St. Johns River Water Management District (Fig. 2-4). This WMA is managed directly by the FGFWFC and is operated in a manner similar to Three Lakes WMA. Prescribed, rotational, winter burns are the major habitat management tool, and cattle grazing is excluded on the area. Hunting season is late September through mid-April and includes deer, wild hog, small game, and spring turkey hunts; no trapping is allowed. Public access is limited to one entrance south of US 192.

On the southwest side of the study area, the Kissimmee River is the site of an extensive land acquisition program of the South Florida Water Management District (SFWMD), aimed at habitat and hydroperiod restoration. During the 1960's, the originally meandering 157-km

Kissimmee River was channelized by the U.S. Army Corps of Engineers to facilitate flood control. As a result of the canal, approximately 81,000 ha of river marsh and other wetlands were lost, groundwater levels were lowered, and water quality in the river was adversely affected (Florida Dept. Environ. Regulation (FDER) 1987).

Since 1973, restoration of the Kissimmee River has been studied. In 1984, the SFWMD began a restoration demonstration project along 19 km of the northern reaches of the river to test methods of reestablishing the natural water regime in the river valley. Land acquisition is a major necessity in river restoration. Total restoration will require the acquisition of over 20,200 ha of original floodplain (FDER 1987).

In addition to the southernmost portion of Three Lakes WMA, there are 2 large public landholdings on the river. In 1985, 3,100 ha on the west side of the river, across from the southern extension of Three Lakes WMA, were acquired by SFWMD through the "Save Our Rivers" funds. In addition to water management by the district, these lands will be managed for wildlife by FGFWFC as the Kicco Wildlife Management Area (Fig. 2-4). Management objectives of the FGFWFC, including a decision on public access for hunting, have yet to be finalized for this area (B. Millsap, FGFWFC, pers. commun., 1987).

Adjoining Kicco WMA is the U.S. Air Force's Avon Park Bombing Range, an extensive 43,300-ha area (Fig. 2-4). In additional to its use as a bombing range, Avon Park is managed for cattle, timber, and public recreational use, including hunting. It supports one of the state's largest range management programs on a public property with over 37,550 ha leased for grazing (G. Tanner, Univ. Florida, pers.

commun., 1988). Avon Park Bombing Range is estimated to have a crane population of 30 pairs and was initially considered as a potential reintroduction site for whooping cranes (Nesbitt 1982).

The Kissimmee Prairie has continued to maintain its rural character despite the tremendous growth in the northern portions of Osceola County associated with Walt Disney World/Epcot Center (Table 2-1). Aside from development associated with the small towns of Yeehaw Junction, Kenansville, and Fort Drum, there are limited developed areas between Lake Kissimmee, the Kissimmee River and the St. Johns River, and south to Fort Drum. On the north side of the study area, there are small housing tracts on and near the northeast side of Lake Marian. On the southeast side of the study area near Fort Drum, there are 3 ranchette developments, including a large, relatively unpopulated development approximately 3 km south of the NAS Kissimmee Prairie Sanctuary.

A long-term potential threat to the Kissimmee Prairie is the possible construction of a high-speed rail transportation system linking Orlando to Miami. While a decision on the system will not be made by the State of Florida until 1991, the current proposal includes a rail system that would pass through the eastern portions of the study area (High Speed Rail Transportation 1987). If any rail stops were to be approved in towns like Yeehaw Junction, development would probably occur in the area.

Given the recreational possibilities associated with both Lakes Kissimmee and Marian, development pressures are likely to surface in this area. A few years ago, Osceola County approved a proposal to build an RV park on a site immediately north of Lake Marian. Although the plans were dropped due to financial problems of the developer, the land is still zoned for recreational development. West of the Kissimmee River, and south of SR 60, are a number of retirement villages. Some of the large private landholdings might eventually be sold for similar developments.

Aerial hazards on the Kissimmee Prairie include powerlines and radio towers. There are 2 adjacent north-south 500 kV transmission lines on the far east side of the study area and a 230 kV transmission line that crosses CR 523 approximately 40 km northwest of Kenansville (Fig. 2-4). No transmission lines cross any of the proposed reintroduction sites. There are several radio towers in the area, although most are north of Lake Marian, or along the Kissimmee River (Appendix B).

Discussion

Given the current land use situation, all 3 study areas could support the reintroduction of whooping cranes. The proposed sites are all large public landholdings with contiguous private, open lands. Suitable crane habitat in the form of dry and wet prairie, improved pasture, and in particular, wetlands, are available in sufficient quantities.

Although Florida has lost large amounts of wetlands to drainage in the past, current regulations are aimed at protecting wetlands on private and public lands. Wetlands falling under the jurisdiction of the state's regional water management districts, including "waters in the state", and agricultural and silvicultural water management systems, are protected primarily through the permitting program for construction and operation of surface water management systems.

Under the water management districts' jurisdiction, preservation of existing wetlands is considered the preferred alternative to any mitigation, destruction, or compensation. Depending on the particular water management district, regulations adopted in 1987 protect isolated wetlands >0 or >0.4 ha from destruction or alteration without appropriate mitigation. Other regulations prohibit ditching, draining, or any other activities that divert surface flow from agricultural lands, unless a permit is obtained (Florida Statute 403.927). Wetlands falling under the jurisdiction of Florida Department of Environmental Regulation (FDER), "waters of the state" are protected in similar ways under the Henderson Wetlands Protection Act of 1984 (Florida Statute 403.927) through permitting programs.

Although wetlands habitats are now protected throughout Florida, the losses of the adjoining upland areas to development decrease the amount of suitable habitat available to cranes. Of the 3 proposed reintroduction sites, the 2 sites in Southwest Florida (Myakka River SP and Webb WMA) face increasing development pressures in and around their boundaries. Housing developments occur along portions of the western and northern boundaries of Myakka River SP. All but the eastern boundary of the Webb WMA has some development.

The high population growth in coastal areas and the completion of I-75 are the 2 major forces shaping these development pressures. Forecasts for the future indicate that the human population will continue to grow in both of these areas (Table 2-1).

While rural zoning ordinances often prohibit development of high density housing, the result is an undesirable rural sprawl created by the proliferation of >2-ha ranchettes. Development also potentially causes disturbance to cranes and other wildlife, due to the activities of both humans and domestic animals. While cranes will tolerate some human activity, and in rare instances become relatively tame, for the most part they prefer large open spaces with minimum disturbance (See Chapter III). Studies of Florida sandhill cranes on the Kissimmee Prairie (see Chapter IV) have determined that cranes maintain year-round home ranges of 1.83 ± 1.03 km^2 (SD). They prefer herbaceous wetlands, and open upland areas.

The habitat fragmentation caused by development forces cranes to either travel longer distances to foraging and roosting sites, or to temporarily or permanently abandon areas. In particular, habitat conditions in and around nest wetlands are crucial because breeding pairs usually stay in the vicinity of the nest pond during both the nesting and prefledging period.

Activities and land uses outside the boundaries of managed areas have many undesirable affects on species and ecological processes within those areas (Schonewald-Cox and Bayless 1986, Noss 1987). While the Webb WMA and Myakka River SP preserve large tracts of suitable crane habitat, human populations continue to surround the boundaries which often impose undesirable restrictions on habitat management and, in particular, on prescribed burning practices. Smoke from prescribed burns frequently is objectionable to the public. And at the same time, the proximity of houses to public land boundaries forces site managers to be very cautious to prevent fires from spreading across boundaries.

Population growth in the Webb WMA and Myakka River SP areas also has increased the demand for potable water. Because desalinization is still an expensive method to treat water, there is an increasing demand for fresh water sources. Recent approval to install 5 shallow wells on the Webb WMA for the future county jail is an example of this trend. In all 3 areas, steps should be taken to assure that no habitat degradation or undesirable decrease in the hydroperiod occurs as a result of pumping on or nearby the proposed reintroduction sites.

Given the future prospects for continued development around the Webb WMA and Myakka River SP, the Kissimmee Prairie should be ranked as the first priority site for the potential reintroduction of whooping cranes in Florida. In addition to the proposed reintroduction sites on the Kissimmee Prairie (Three Lakes WMA and Kissimmee Prairie Sanctuary), there are large public landholdings in the immediate area. These public lands and the surrounding large, private landholdings provide optimum conditions for the expansion of both the Florida sandhill and whooping crane populations.

At this point in time, the Webb WMA should be ranked as the second priority site for the reintroduction of whooping cranes. The Webb WMA represents the largest public-owned area of the 3 sites considered (26,454 ha), and is managed by only one state agency, the FGFWFC. It supports a large population of resident Florida sandhill cranes (see Chapter III), and manages for crane habitat with its active controlled spring burn program.

Myakka River SP should be ranked as the third priority site. When combined with the Sarasota County Ringling-MacArthur Reserve these 2 properties include 21,500 ha of public lands. Until the remaining

3,240-ha inholding on the Ringling-MacArthur Reserve is purchased, however, there is still the possibility of future development. While habitat conditions on Myakka River SP have improved with the controlled burn program, in some parts saw-palmetto is still rank.

Important to the future of any reintroduction scheme is the continued existence of large tracts of undeveloped private lands. My breeding surveys and home range studies on the Kissimmee Prairie have indicated a strong preference by cranes for herbaceous emergent wetlands and improved pasture (see Chapters III and IV). While most of the private landowners on all 3 areas have a strong appreciation for wildlife, economic constraints may, in time, force them to maximize their financial gain from their lands in order to pay taxes and to profit during periods of declining beef prices. Insufficient funds are available to purchase open lands; therefore, some alternative strategies should be examined to encourage the continued existence of these large undeveloped lands.

CHAPTER III
PRODUCTIVITY OF FLORIDA SANDHILL CRANES ON THREE SITES IN CENTRAL FLORIDA

Introduction

Aerial surveys using either photography or trained observers can be an effective method of censusing crane populations. When a species or its nest is large or conspicuous, and the census area is large and not readily accessible by ground, aerial surveys may be the only practical means to obtain the necessary information. Choice of the aerial censusing technique to be used, visual-count or aerial photography, will depend on the spatial distribution of the crane population being studied. When cranes are concentrated in large flocks such as migratory staging areas and wintering grounds, visual counts by observers may be impractical. Blackman (1979) estimated Brolga crane (*Grus rubicundus*) populations in Australia by photographing concentrated and dispersed flocks during the non-breeding season. Techniques combining aerial photography and visual counts have been used successfully to estimate numbers of sandhill cranes staging in the central Platte River Valley in Nebraska (Ferguson et al. 1979, Benning and Johnson 1987), and for wattled cranes (*Grus carunculatus*) in Zambia (Douthwaite 1974).

Population estimates of breeding cranes from aerial surveys traditionally have relied on visual counts. Seasonal breeding pair estimates usually are determined from total coverage of an area(s) over a 2-3 day period each year. Examples were the simultaneous aerial surveys for breeding red-crowned cranes (Grus japonensis) conducted in Japan (Masatomi et al. 1985), the People's Republic of China (Ma and Jin 1987, Feng and Li in press), and the Soviet Union (Shibaev 1985, Smirensky et al. 1985).

While a total count of a crane population using aerial techniques may be a desired objective, it can be difficult and expensive to achieve because total counts require good maps, complete coverage of the census area, and an assurance that all animals are counted (Norton-Griffiths 1975). A preferred and less expensive alternative to a total population count is aerial sampling. There are 3 basic aerial sampling methods: quadrat, block and transect. In quadrat sampling, a census zone is divided into quadrats that usually are square shaped. During the census, the entire sampled quadrat is intensively searched and all animals within the quadrat are counted. Block sampling is similar to quadrats; however, the boundaries are physical features identifiable on the ground. As in quadrat sampling, each sampled unit is entirely searched, and all animals counted (Norton-Griffiths 1975).

Transect sampling, counting animals while flying in a straight line from 1 side of the sampling unit to the other, is the most popular method and offers several advantages. It is cost effective, physically comfortable for the observer, and easy to navigate and orient. With respect to statistical analyses, transects produce a lower variance and sampling error than blocks or quadrats. This is because transects tend to reduce the effect on sample error caused by animals clumping together (Norton-Griffiths 1975).

From 1984 to 1986, I conducted aerial transect surveys for nesting Florida sandhill cranes in central Florida. The Florida sandhill crane is a nonmigratory subspecies in the United States that occurs from Okefenokee Swamp in southeast Georgia south to the Florida Everglades. In central Florida, this subspecies has a long nesting season, extending from January through the end of May.

Previous to this study, most of the available information on productivity of sandhill cranes in central Florida was derived from 2 studies. Walkinshaw (1976, 1982, 1987) reported productivity data from over 150 Florida sandhill crane nests on the Kissimmee Prairie during 1967-87. Layne (1983) monitored Florida sandhill crane pairs with young during 1973-79 summer and fall road surveys in south-central Florida.

Nest surveys coupled with fall roadside juvenile recruitment surveys were part of a larger study designed to evaluate 3 Florida sites proposed for whooping crane reintroduction. The revised edition of the Whooping Crane Recovery Plan (U.S. Dept. Interior 1986) has identified several biological criteria that all third whooping crane population studies need to address. One of these criteria includes determining which aspects of the biology of the resident sandhill crane populations would be affected by reintroduction of whooping cranes.

The objectives of the nest surveys were to (1) map the seasonal distribution of nesting Florida sandhill crane pairs on the 3 sites and their surrounding areas, (2) estimate the density of the Florida sandhill crane breeding population on the 3 sites and their surrounding areas, (3) determine what factors are influencing breeding, and

(4) characterize the nest sites selected, and (5) subsequently determine annual recruitment of fledged juveniles and brood size.

Methods

From 1984 to 1986, field studies were conducted on 3 sites in central Florida. These included the Kissimmee Prairie in Osceola and Okeechobee counties (including Three Lakes Wildlife Management Area and the National Audubon Society Ordway-Whittell Kissimmee Prairie Sanctuary), Myakka River State Park (SP) in Sarasota and Manatee counties, and the C.M. Webb Wildlife Management Area (WMA) in Charlotte County (see Fig. 1-1). Study areas included not only the potential whooping crane reintroduction sites but also the surrounding areas. See Chapter II for descriptions of locations and habitats.

Rainfall occurs unevenly throughout the year on all 3 areas. Florida sandhill crane nesting occurs during the dry season, November through April. During the wet season, from May to October, 70-80% of the rainfall occurs (Fig. 3-1).

Aerial Surveys of Nests

Aerial sampling for Florida sandhill crane nests was considered the most accurate and efficient means of estimating the size of the local breeding populations due to the long breeding season, the large size of the proposed release sites, the great distances between sites, and the heterogeneous terrain.

Sampling regime. Aerial surveys were conducted in all study areas approximately once every 2-3 weeks (range 8-34 days). Surveys began in

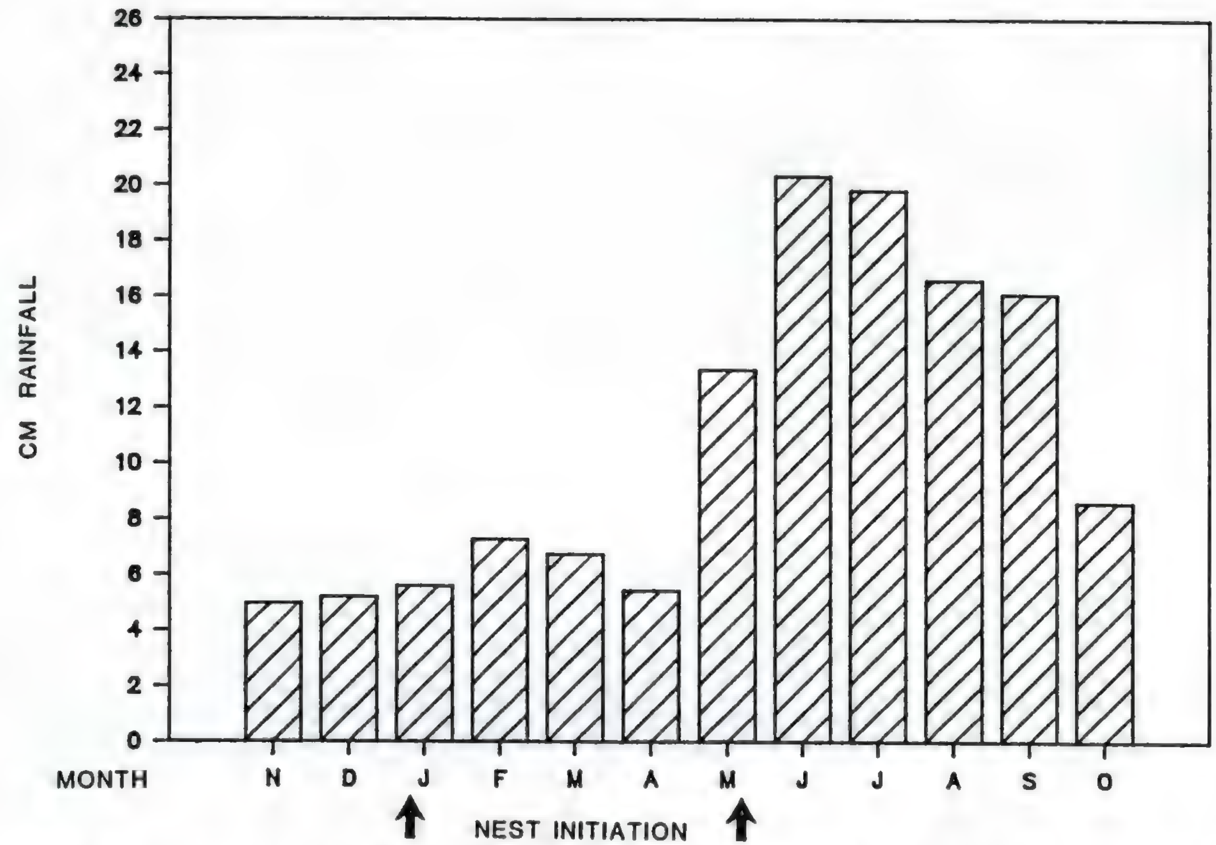

Figure 3-1. Florida sandhill crane nesting season and the average monthly rainfall (cm) for November through October on the Kissimmee Prairie, Florida.

mid-January and were completed by mid-May, except in 1984 when surveys began on 1 March. All regular surveys were conducted from a Cessna 172 Skyhawk flying at a speed of 145 km/h.

For the 1984 season, parallel east-west transects, approximately 1.6 km apart, were flown at a height of 75 m across each study area. A strip width was not defined for each transect; however, most observations occurred within 0.2 km on each side of the plane. The pilot looked for nesting cranes out the port side of the plane while I observed out the starboard side.

For the 1985 and 1986 aerial surveys, systematic aerial fixed-strip transects were developed. Compared to random sampling, systematic sampling is the more efficient means of mapping the distribution of animals and making comparisons of the numbers observed on a specific site over time. Systematic sampling also avoids the navigational problems associated with random transect sampling (Caughley 1977). When this study began, systematic aerial fixed-strip transect sampling already was being used successfully in the Everglades National Park (South Florida Research Center 1985) to estimate the population size and distribution of wading birds.

With systematic aerial transect sampling, predetermined and consistently-spaced parallel transects are flown across the study area. Initially, a grid system is established, then east-west flight lines are spaced to bisect each row of grid squares. For this study, a 3 km x 3 km grid system was established for each study area (Fig. 3-2). Transect flights were accurately repeated using a Loran-C navigation receiver that had been previously programmed with each transect's starting and ending points, and calibrated at the beginning of each

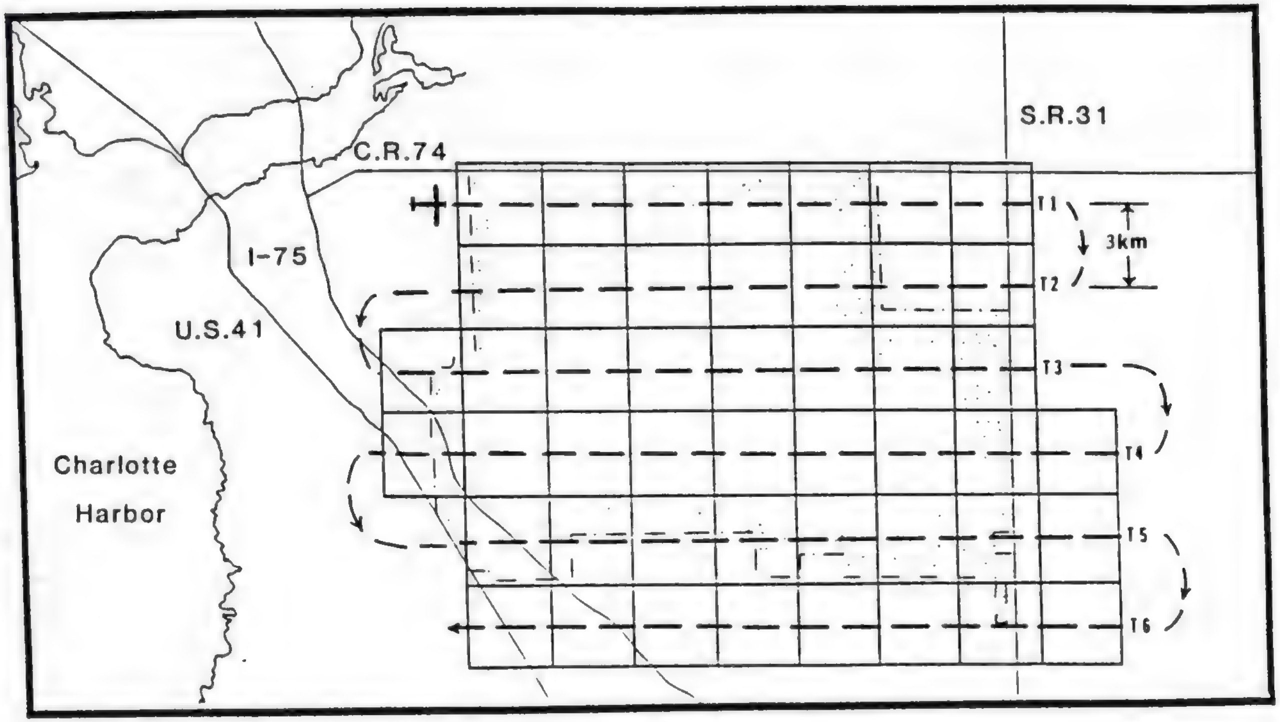

Figure 3-2. Layout of a systematic aerial fixed-strip transect survey using 3 km x 3 km grid mapping on the Webb Wildlife Management Area, Florida. Boundaries of Management Area are shaded.

flight at a predetermined location. Transect lengths varied within and between each study area as most latitudinal starting and ending points were landmarks such as powerlines, roads, or lakes.

For 1985 and 1986 aerial surveys, a field assistant replaced the pilot as the second observer. Each of the 2 observers, 1 in the front with the pilot and the other in the back seat directly behind the pilot, recorded all active nests detected within a 160 or 200 m interval. Thus, 12-13% of each study area was sampled during each survey. The fixed-strip width for each observer was established by maintaining a constant plane height of 91 m and defining each observer's visual boundaries (Fig. 3-3). Each observer's strip width was defined by that area viewed between 2 streamers attached to the wing struts and marks on the windows. The exact position of the streamers and window marks were calculated using a method outlined by Pennycuick and Western (1972).

Florida sandhill cranes in central Florida generally build their nests with emergent vegetation in relatively shallow wetlands <1 m deep (Walkinshaw 1981, this study). Nests in upland habitats are rare and have been reported on only a few occasions during this century. Although sandhill cranes are difficult to observe from fixed-wing aircraft because of their cryptic coloration, their nests usually are large and conspicuous. Because the cranes often construct more than 1 nest platform, I recorded observations as a nest only if (1) a crane was present, (2) an egg was visible, but no crane was present, or (3) adult cranes and chicks were on the nest.

During the 1985 and 1986 flights I was able to identify individual nests by recording Loran-C locations and making diagrams of the

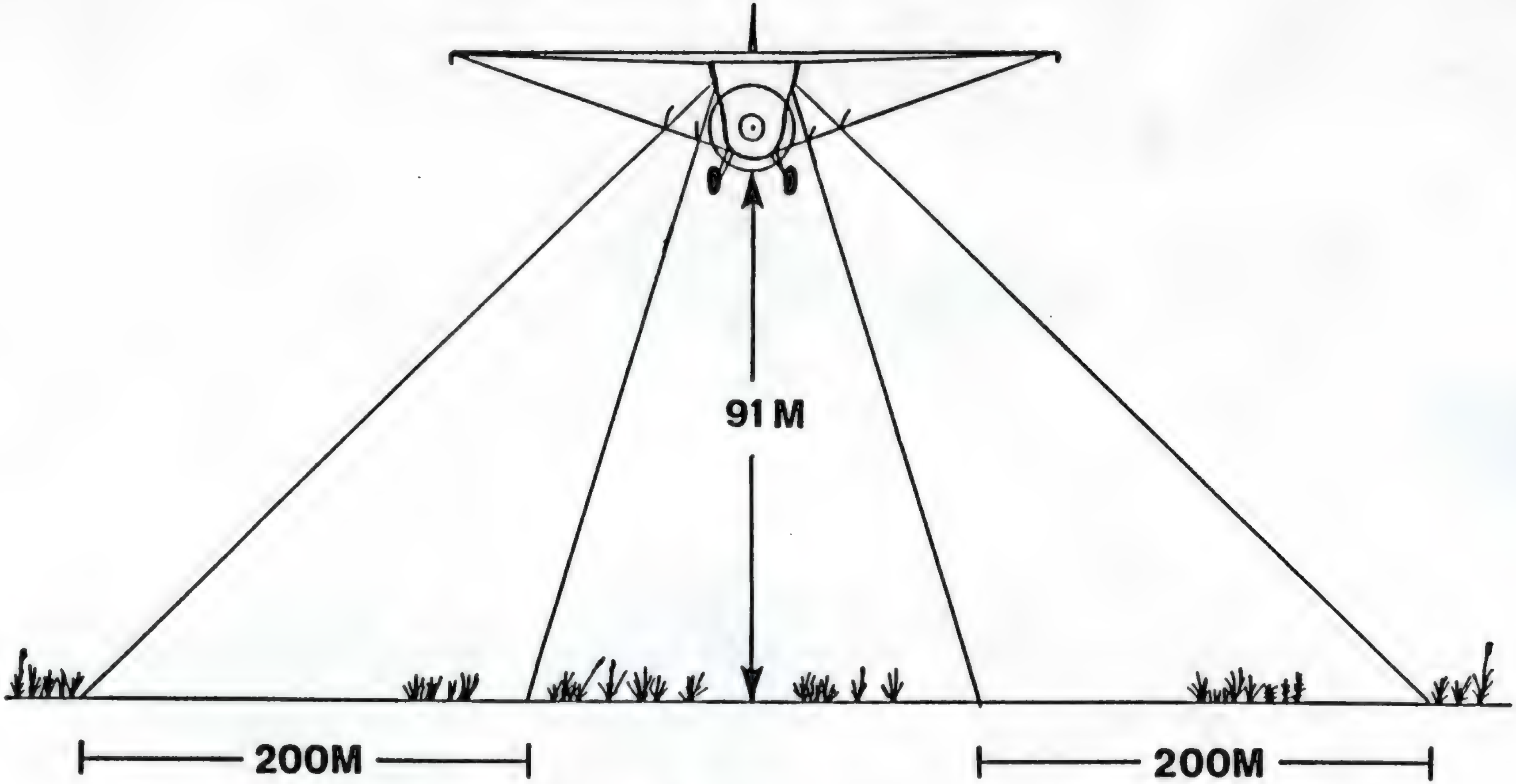

Figure 3-3. Diagram of plane height and observer strip width used during systematic aerial transect surveys for breeding Florida sandhill cranes on 3 sites in central Florida (from: Jelks and Collopy 1987).

wetland's shape and the nest's position in it. In this study, I found that nautical distance to the end of the transect was faster and less confusing to determine and record than the longitude. After each flight I pinpointed the nest using a combination of 1:24,000 Mark Hurd aerial photograph maps and U.S. Geological Survey (USGS) topographic maps.

<u>Areas surveyed</u>. The Webb WMA survey area included approximately 405 km^2. Flight transects began at the northwest corner of the Webb and ended 3 km south of the Webb (see Fig. 2-1). During 1984, between 9 and 12 transects were flown per flight for a total of 204-240 km. For 1985 and 1986, 6 transects were flown per flight for 135 km. Transects were 20-25.8 km long, and traversed the entire width of the Webb from I-75 to SR 31 during 1984, and from US 41 to SR 31 during 1985 and 1986. Three transects extended approximately 4 km east into Babcock Ranch during 1985 and 1986.

The Myakka River SP survey area included approximately 597 km^2 in 1984 and 1985, and 694 km^2 in 1986. Areas surveyed included Myakka River SP, Sarasota County Ringling-MacArthur Reserve, and surrounding private ranches. For 1984 and 1985, flight transects began at Sugar Bowl Road, approximately 11.3 km north of SR 72, and ended approximately 2.5 km north of I-75 (see Fig. 2-3). For 1986, 2 transects were added at the north end of the study area, accounting for approximately 35 km. Transects oriented east-west extended approximately 24.5 km from Sugar Bowl Road to a major north-south powerline. South of SR 72, transects were extended on the east side approximately 6 km. For 1984, between 7 and 12 transects per flight covered 172-295 km, respectively. During 1985, 7 transects usually were flown, totalling 188 km. With the exception of 1 helicopter flight, for 1986 surveys, 8 or 9 transects were flown for a total of 219-229 km.

The Kissimmee Prairie survey area included 1058 km^2 in 1984 and 1985, and 1,182 km^2 in 1986. Areas surveyed included the portions of Three Lakes WMA south of the Florida Turnpike, Prairie-Lakes State Preserve, and NAS Kissimmee Prairie Sanctuary, as well as surrounding private ranches. Transects began at the intersection of CR 523 and Overstreet Road, approximately 1.5 km southeast of the northwest boundary of Three Lakes WMA (see Fig. 2-4). Transects ended approximately 3 km south of the Kissimmee Prairie Sanctuary in Okeechobee County. Because of the configuration of the region surveyed, transect length varied from 4.8-28.7 km long during 1984, and 9.3-31.3 km during 1985 and 1986. Transects, oriented east-west, usually were traversed from the Florida Turnpike to Lake Kissimmee south to Kenansville. Transects south of Kenansville extended from US 441 to Lake Kissimmee or else to within 1.7 to 12 km of the Kissimmee River.

For the 1986 surveys, 7 transects (Nos. 5-11) were extended past US 441 to a major north-south powerline. In all, between 16 and 26 transects were flown per survey for 293-488 km during 1984. During 1985 and 1986, either 17 or 18 transects were flown per survey for 330-405 km. On 2 occasions, 24 March and 1 April 1986, 5 and 6 extra transects were flown over Three Lakes WMA for an additional 36.6 and 43.6 km, respectively. These transects were parallel to the regular transects and at approximately 1.5-km intervals from the usual transects; the length of these transects varied from 4.8 to 8.2 km.

Detectability. In 1985 and 1986, I conducted a series of 3 experiments to determine how aerial censusing methods and flight speed affected nest detectability. In 1985, I censused study areas using both the fixed-strip transect and the quadrat sampling methods. Immediately following completion of a transect survey, 3 to 6, pre-selected 3 km x 3 km grid cells (quadrats) were searched for nests.

Helicopters were used to test how flight speed effects detectability. In 1985 and 1986, each area was surveyed by helicopter once each season. In 1985, the 6 pre-selected quadrats on each study area were searched for nests by fixed-wing aircraft, and then by helicopter within 3 days. In 1986, fixed-strip aerial transect surveys were flown by helicopter in a subset of the previously surveyed transects. These flights were conducted once in Webb WMA and Myakka River SP and on 2 occasions in the Kissimmee Prairie.

Breeding pair population estimates. In order to estimate the breeding population from the fixed-strip transect surveys, I used a ratio-estimation method for unequal length transects. This method was popularized by Jolly (1969a) and is referred to as the Jolly II method.

The crude density of breeding pairs/km^2, $\hat{R}$, for each survey was estimated using the following formula:

$$\hat{R} = \Sigma y / \Sigma z$$

where y is the number of nests counted in the transect and z is the area (transect length multiplied by total strip width) of a sample transect.

The estimated population size for each survey is:

$$\hat{Y} = \hat{R} * Z$$

where $\hat{Y}$ is the estimated breeding population, Z is the total area of the census zone, and $\hat{R}$ is the estimated density.

The sample error of $\hat{Y}$, $SE(\hat{Y})$, is estimated as $\sqrt{\underline{s}^2 (\hat{Y})}$ where

$$\underline{s}^2(\hat{Y}) = (N(N-n)/n) * (S_y{}^2 - (2 * \hat{R} * S_{zy}) + (\hat{R}^2 * S_z{}^2))$$

In this formula, $\underline{s}^2(\hat{Y})$ is the sample variance of $\hat{Y}$, N is the number of possible transects in the population, n is the number of transects in the sample, $S_y{}^2$ is the variance in number of nests counted in the transects, S_{zy} is the covariance between the nests counted and the area per transect, and $S_z{}^2$ is the variance between the areas of all the sample transects.

The 95% confidence interval (CI) of $\hat{Y}$ is:

$$CI = \pm t * SE(\hat{Y})$$

where t is for n-1 degrees of freedom, and n is the number of transects.

For 1985 and 1986 data, I estimated a breeding population for the entire season, by totaling only initial nest sightings (no repeat sightings) for each transect for all flights combined. Crude density, total breeding pairs, and sample error were calculated using the above formulae. Final estimations were then adjusted downward to account for renesting. I used a 35% adjustment figure based on a recent study of the incidence of renesting in Florida sandhill cranes (S. Nesbitt, FGFWFC, pers. commun., 1987).

For quadrat sampling, I used the Jolly I method (Jolly 1969a) for equal-sized sampling units to estimate the breeding pair population and 95% confidence limits. With this method, the population estimate is calculated from the average number of nests counted in each quadrat and the population variance is calculated from counts among quadrats.

Environmental Correlates of Nesting Densities

I analyzed breeding pair densities for all fixed-wing flights with respect to several environmental variables. These included photoperiod, water levels, drying and rising rate, rainfall, and temperature.

Water levels from shallow (<11 m) groundwater wells monitored by the USGS were used as an index of surface conditions. On the Myakka River SP and Kissimmee Prairie study areas, maximum daily water levels were available. On the Webb study area, daily water levels were interpolated from monthly groundwater well readings (USGS files), assuming uniform changes between sampling dates. A daily drying or rising rate was calculated as the difference from the previous day's water level. Daily rainfall and maximum and minimum temperature data were obtained from weather stations of the National Oceanic and Atmospheric Administration and the South Florida Water Management District. All weather and groundwater well data were collected either on the study area or within 4.5 km of a study area boundary.

I used the Statistical Analysis System (SAS) (SAS Inst. 1985a) to perform statistical summaries and analyses. Spearman rank correlations were used to investigate the associations between breeding pair densities by flight and environmental variables. I then used stepwise regression to determine which variables were the best predictors of breeding pair densities. The dependent variable, breeding pair density, was weighted by the standard error. Only crude densities determined from fixed-wing transect surveys were used in these analyses. The critical level for rejecting a null hypothesis was $P < 0.05$.

Nest Site Characteristics

Nests identified during aerial surveys during the 1985 and 1986 seasons were plotted on aerial photographs. Land ownership was determined from courthouse records for nests in Okeechobee County, and the published plat books for nests in Osceola, Sarasota, Manatee, and Charlotte counties (Rockford Map Publishers 1982a,b; Florida Plats 1984, 1985).

For Myakka River SP and the Webb WMA, each nest was assigned a wetland code based on the National Wetlands Inventory 1:24,000 scale map of the region (Cowardin et al. 1979). For the Kissimmee Prairie, wetland codes were determined from ground truthing and aerial photographs. Aerial photographs of 1:4,800 scale were used to determine the size of the wetland and the surrounding land use. On the Webb WMA, FDOT vegetation maps (FDOT 1978) were used as supplemental information.

On the Kissimmee Prairie, nests previously located from aerial transects and from ground searches of selected areas were visited following hatching. Nest site characteristics (size, composition of nest, height and type of surrounding dominant vegetation, shoreline) and evidence of hatching success were recorded for 74 nests.

Fall Juvenile Recruitment Surveys

In order to obtain an estimate of the average brood size and annual juvenile recruitment for the 3 areas, surveys for juvenile-plumaged cranes were conducted between August and October, before the arrival of migratory greater sandhill cranes. Juvenile recruitment surveys consisted of counting all cranes observed over a 2-3 day period while driving public and private roads, and observing known off-road traditional use areas and roost sites on and around the study area. Feeding and roosting concentrations located as far as 18 km from the study areas' boundaries were included in the overall counts. With the exception of 1984 when only 1 survey was made at Myakka River SP area, 2 surveys were conducted on each study area per year.

Results

Nesting Chronology and Density

1984 Breeding season. Eleven flight days during Spring 1984 resulted in 5 surveys of Webb WMA, 4 surveys of Myakka River SP, and 5 surveys of the Kissimmee Prairie study areas. A flight on 29 February over the Webb WMA study area served principally to refine census techniques. The last survey was completed on 14 May 1984.

Water levels in shallow groundwater wells throughout the 1984 breeding season were higher than either 1985 or 1986. These higher levels initially were the result of above normal precipitation on the 3 areas during November and December (Table 3-1). Both the Kissimmee Prairie and Webb WMA study areas both had precipitation slightly above normal for November and December (15.3 cm and 14.9 cm, respectively), and close to average rainfall during January (2.0 cm and 1.5 cm, respectively). Myakka River SP, however, had unusually wet conditions due to heavy rainfall during November and December. A total of 32 cm of precipitation fell during this period, approximately 21 cm above the normal rainfall for these months. While water levels began to fall throughout January and February, precipitation in late February and

Table 3-1. Total precipitation and departure from normal (cm) on 3 study areas in central Florida for 1 May 1983 - 30 April 1984.

	Kissimmee Prairie[a]		Myakka River SP[b]		Webb WMA[b]	
Month/yr	Precip	Depart	Precip	Depart	Precip	Depart
May 1983	5.0	-8.4	5.1	-4.7	2.2	-8.0
Jun 1983	24.2	3.8	23.7	2.5	17.9	-1.9
Jul 1983	9.5	-10.5	30.2	8.8	15.7	-2.0
Aug 1983	9.5	-7.2	18.8	-4.9	17.1	-2.0
Sep 1983	12.2	-4.2	29.6	7.8	24.6	5.5
Oct 1983	11.5	2.6	6.8	-1.8	10.5	1.0
Nov 1983	4.8	0.0	11.2	5.8	8.3	4.3
Dec 1983	10.5	5.3	20.8	15.3	6.6	2.1
Jan 1984	2.0	-3.6	2.5	-3.9	1.5	-3.9
Feb 1984	6.4	-1.1	6.2	-1.6	8.4	2.5
Mar 1984	5.5	-0.9	13.7	6.6	13.6	7.5
Apr 1984	6.0	0.3	8.4	2.9	8.2	3.7
Total	107.1	-23.9	177.0	32.8	134.6	8.8

[a] Calculated from S-65 dock at south end of Lake Kissimmee, South Florida Water Manage. District, unpubl. data 1985.

[b] U.S. Dep. Comm. 1983, 1984.

March caused a series of rising water levels that were sustained until mid-April (Figs. 3-4, 3-5, 3-6).

Peak nesting for 1984 was observed on all 3 areas during the 9-10 March aerial surveys (Table 3-2, Figs. 3-4, 3-5, 3-6). On subsequent surveys, nest counts dropped by 40 to 60%. The number of nests sighted continued to decline throughout the remaining surveys on the Myakka River SP and Kissimmee Prairie areas. Nest counts on the Webb WMA study site, however, did not drop sharply until the final mid-May flight.

Because nesting surveys were not conducted during January and February 1984, it was not possible to document the beginning of the breeding season in that year or to compare the nesting chronology with previously compiled Florida nesting records. The peak counts from the 9-10 March flights on the 3 areas, however, are 2 weeks later than Walkinshaw's (1987) estimated 19-21 February mean (N = 14) for nest initiation on the Kissimmee Prairie.

On the Kissimmee Prairie, 58 nests were located along the transects during 5 aerial surveys. The highest crude nesting density for all 3 study areas in 1984, 0.17 breeding pairs/km^2 (31 nests) were recorded on this study area during the 10 March aerial survey (Fig. 3-4). On Webb WMA study area, 35 nests were located on transects, and peak nesting occurred on 9 March (Fig. 3-6). Compared to the other 2 areas, however, Webb WMA maintained a relatively high density of active nests until the end of April. It is quite likely that the 13 cm rainfall event on 13 March may have flooded nests and stimulated renesting. This speculation is supported by Walkinshaw's (1976)

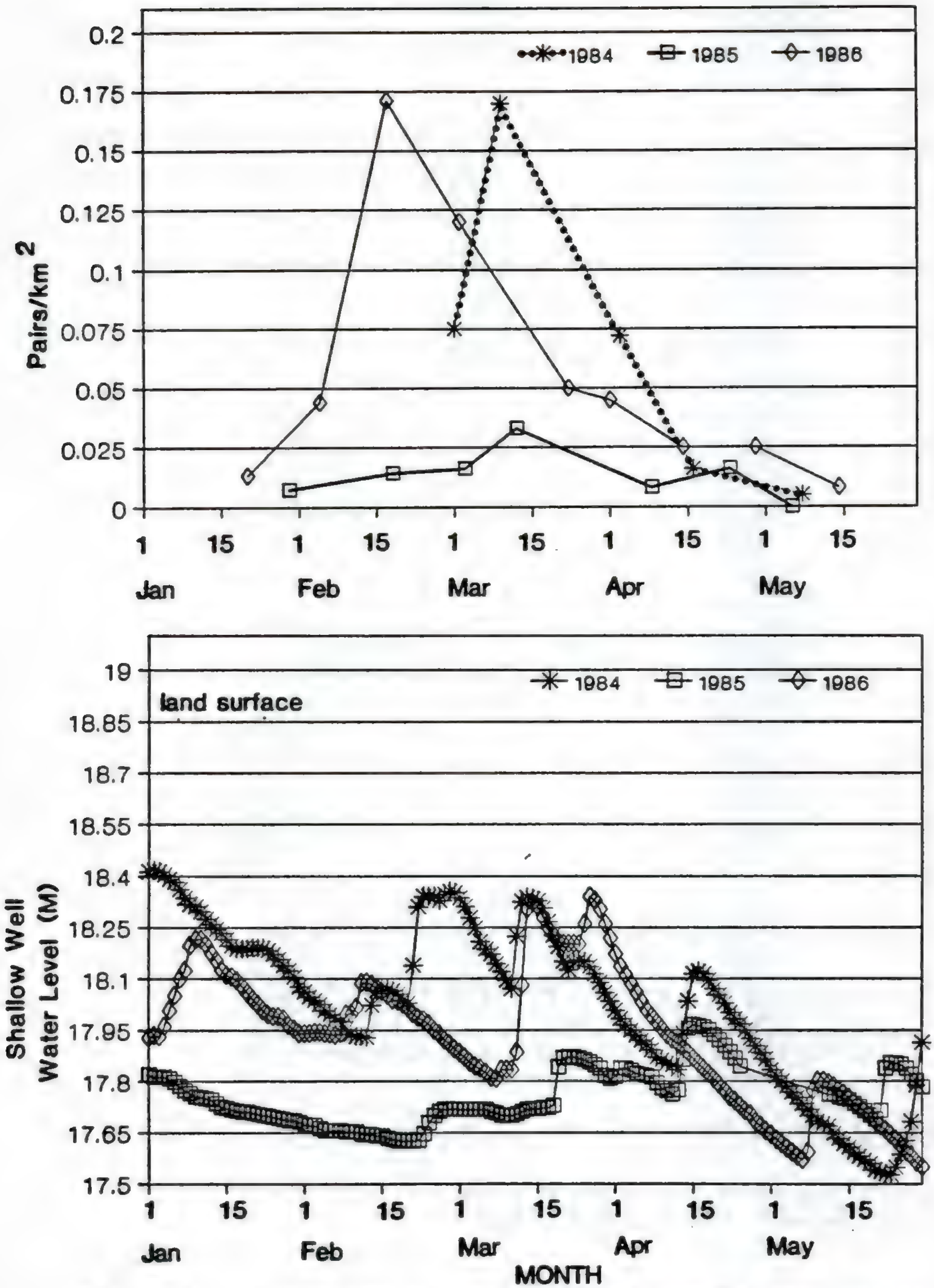

Figure 3-4. Comparison of nesting densities and groundwater-well water levels at Kissimmee Prairie survey area, 1984-1986 breeding seasons. (a) Breeding pair densities as determined from aerial fixed-strip width transect surveys. (b) Daily maximum water levels from shallow well OS182 on Kissimmee Prairie.

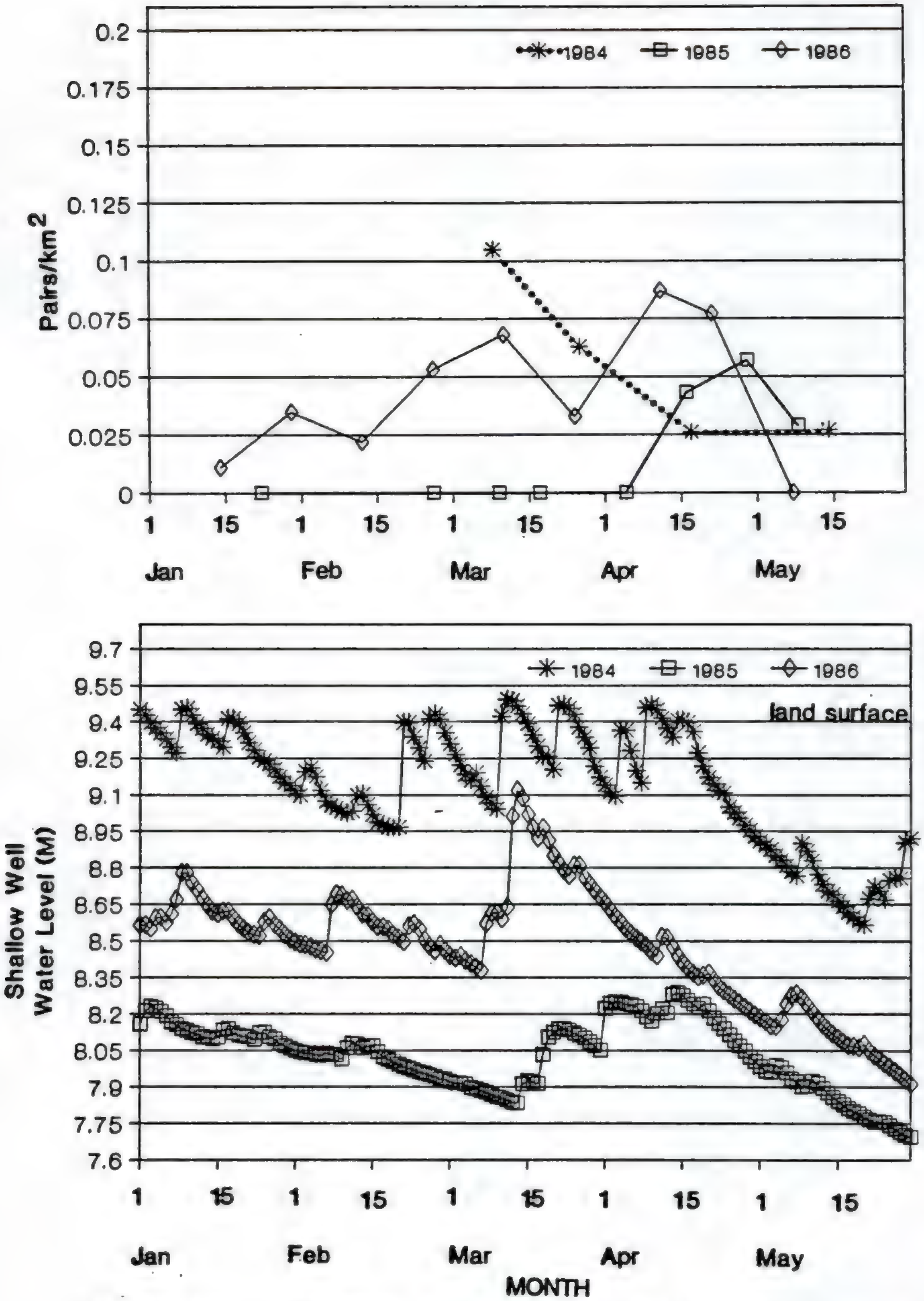

Figure 3-5. Comparison of nesting densities and groundwater-well water levels at Myakka River State Park survey area, 1984-1986 breeding seasons. (a) Breeding pair densities as determined from aerial fixed-strip transect surveys. (b) Daily maximum water levels from shallow well 19E on Sarasota County Ringling-MacArthur Reserve.

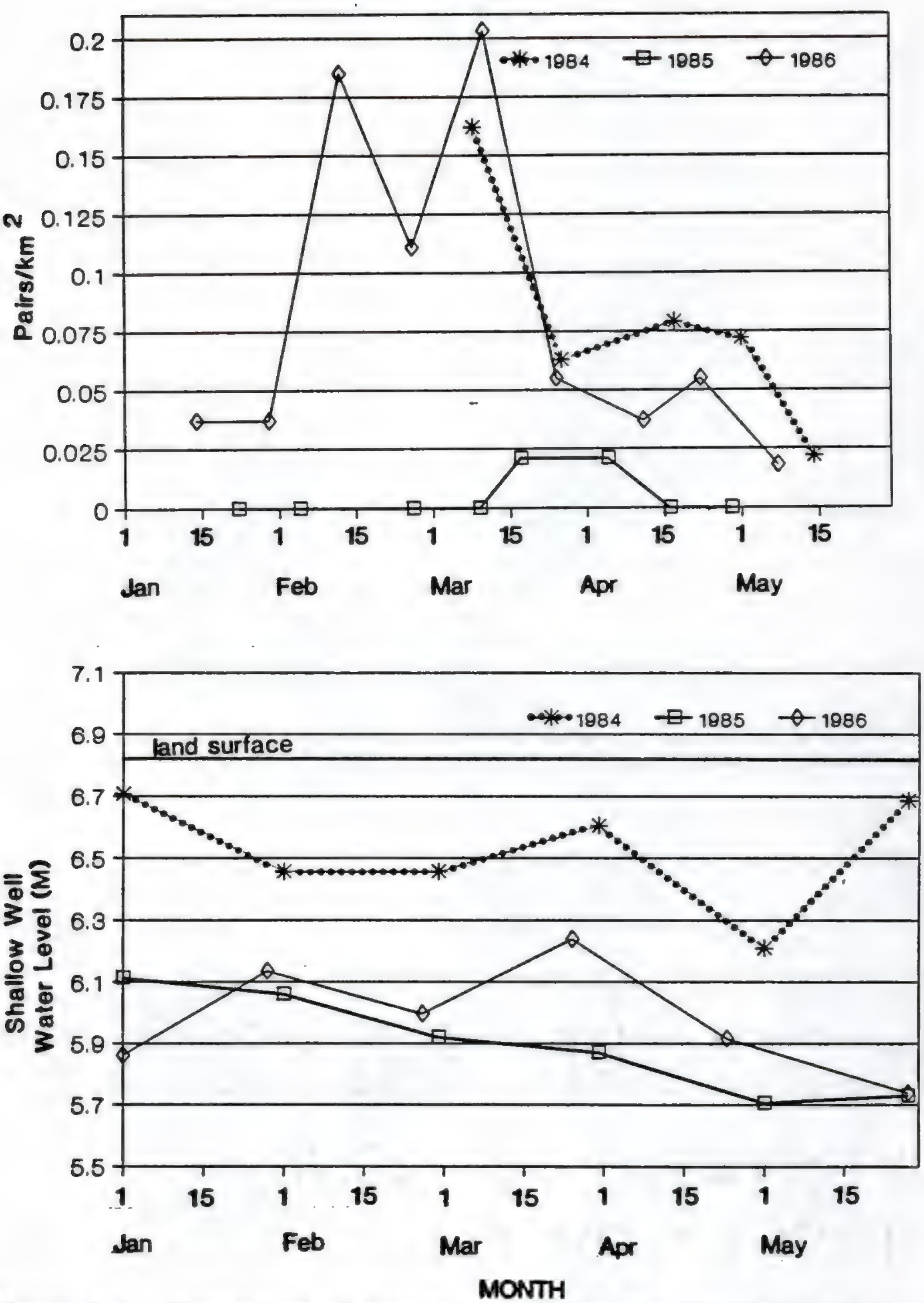

Figure 3-6. Comparison of nesting densities and groundwater-well water levels at Webb WMA survey area, 1984-1986 breeding seasons. (a) Breeding pair densities as determined from aerial fixed-strip transect surveys. (b) Monthly water levels from shallow well L-3209 near Webb WMA.

Table 3-2. Peak nesting date by year as determined from aerial surveys.

	1984[a]	1985	1986
Webb WMA	9 March	19 March 5 April	12 March
Myakka River SP	9 March	29 April	12 April
Kissimmee Prairie	10 March	14 March	17 February

[a] Surveys did not begin until 1 March.

findings that for 75 Florida sandhill crane nests, the average height of a nest above the water was 10.9 cm.

Peak nesting densities occurred at the Myakka River SP study area on 9 March when 11 nests were counted for an estimated 0.11 breeding pairs/km^2 (Fig. 3-5). Despite 8 cm of rain on 13 March, and relatively high water levels through mid-April, Myakka River SP study site did not maintain high nesting densities throughout April. In all, 24 nests were located during 4 surveys on the study area.

1985 Breeding season. In 1985, a severe drought on all 3 study areas caused the majority of wetlands to dry up by early April. From May 1984 to April 1985, all 3 areas recorded below average monthly rainfall in at least 9 of the 12 months (Table 3-3). Similarly, water levels in shallow groundwater wells were substantially lower than 1984. On Myakka River SP, January through April monthly maximum water levels ranged from 76 cm (April) to 112 cm (February and March) lower than the previous season. On the Kissimmee Prairie, monthly maximum water levels ranged from 13 cm (April) to 53 cm (February) lower. On the Webb WMA study area, water levels receded steadily as the season progressed. Rainfall on the Kissimmee Prairie and Myakka River SP study areas caused water levels to rise slightly during March and April (Figs. 3-4, 3-5).

As a consequence of the drought, there were few nesting attempts recorded during the 1985 breeding season (Figs. 3-4, 3-5, 3-6). Estimated crude densities for the breeding season were very low on all 3 study areas and ranged from 0.03 to 0.05 breeding pairs/km^2 (Table 3-4).

Table 3-3. Total precipitation and departure from normal (cm) on 3 study areas in central Florida for 1 May 1984 - 30 April 1985.

	Kissimmee Prairie[a]		Myakka River SP[b]		Webb WMA[c]	
Month/yr	Precip	Depart	Precip	Depart	Precip	Depart
May 1984	16.2	2.8	10.9	1.1	10.9	0.7
Jun 1984	11.5	-8.9	7.3	-13.9	17.6	-2.1
Jul 1984	22.6	2.6	39.3	17.9	25.7	8.0
Aug 1984	14.3	-2.4	18.5	-5.2	13.2	-5.9
Sep 1984	7.4	-9.0	10.6	-11.2	10.2	-8.9
Oct 1984	2.8	-6.1	7.0	-1.5	4.3	-5.2
Nov 1984	10.1	5.3	6.0	0.6	5.3	1.3
Dec 1984	1.4	-3.8	0.9	-4.6	1.7	-2.8
Jan 1985	1.8	-3.8	2.1	-4.4	0.7	-4.7
Feb 1985	1.8	-5.7	2.5	-5.4	2.4	-3.5
Mar 1985	3.7	-2.7	7.1	-0.1	0.6	-5.5
Apr 1985	4.9	-0.8	5.3	-0.2	3.6	-0.8
Total	98.5	-32.5	117.5	-26.9	96.2	-29.4

[a] Calculated from S-65 dock at south end of Lake Kissimmee, South Florida Water Manage. District, unpubl. data 1985.
[b] U.S. Dep. Comm. 1984, 1985.
[c] U.S. Dep. Comm. 1985 and Webb WMA files.

Table 3-4. Estimated crude density ($\hat{R}$), and estimated total breeding pair population by season for 3 study areas in central Florida. Estimates based on initial nest sightings on aerial transects, 1985 and 1986.

	1985			1986		
Area	Area km^2	$\hat{R}/km^2$	Total pairs $\pm$ 95%	Area km^2	$\hat{R}/km^2$	Total pairs $\pm$ 95%
Webb WMA	405	0.03	12 $\pm$ 19	405	0.52	211 $\pm$ 62
Myakka River SP	597	0.05	31 $\pm$ 30	694	0.22	150 $\pm$ 60
Kissimmee Prairie	1,058	0.05	49 $\pm$ 40	1,182	0.25	300 $\pm$ 111

On the Webb WMA study area, observations during the 8 fixed-wing transect surveys, and 1 helicopter quadrat survey included 2 nests on transects (Fig. 3-7), no nests in quadrats, and 3 nests sighted incidentally. Of the 5 nests located, 60% (3) were within the Webb WMA boundaries (Appendix C).

At Myakka River SP study area, the first nest of the 1985 season was observed on 11 March during an aerial search of a quadrat. No nests were counted on the transects until over 1 month later (Fig. 3-5). Peak nesting occurred on 29 April when 4 nests were observed on transects.

During 1985 on Myakka River SP study area, there were 8 fixed-wing transect surveys and 1 helicopter quadrat survey. In all, 12 nests observed from the air on the Myakka River SP study area included 5 transect nests (Fig. 3-8), 3 quadrat nests (Fig. 3-9), and 4 incidentally observed nests. An additional 2 nests were located through ground efforts (H. Jelks, Univ. Florida, pers. commun., 1985). Four nests (29%) were located within the Park, and 1 nest on the Sarasota County Ringling-MacArthur Reserve (Appendix C).

During the 7 aerial nesting surveys on the Kissimmee Prairie in 1985, 8 nests were located on transects (Fig. 3-10) and 1 nest in a quadrat (Fig. 3-11). Another 11 nests and 1 brood of flightless (<60-70 days old) chicks (hereafter referred to as prefledged) were located incidentally from both fixed-wing aircraft and helicopter for a total of 20 nests from the air. When transect nests alone are considered, the estimated 1985 peak nesting period was 14 March (Table 3-2, Fig. 3-4), very close to the 1984 peak on 10 March.

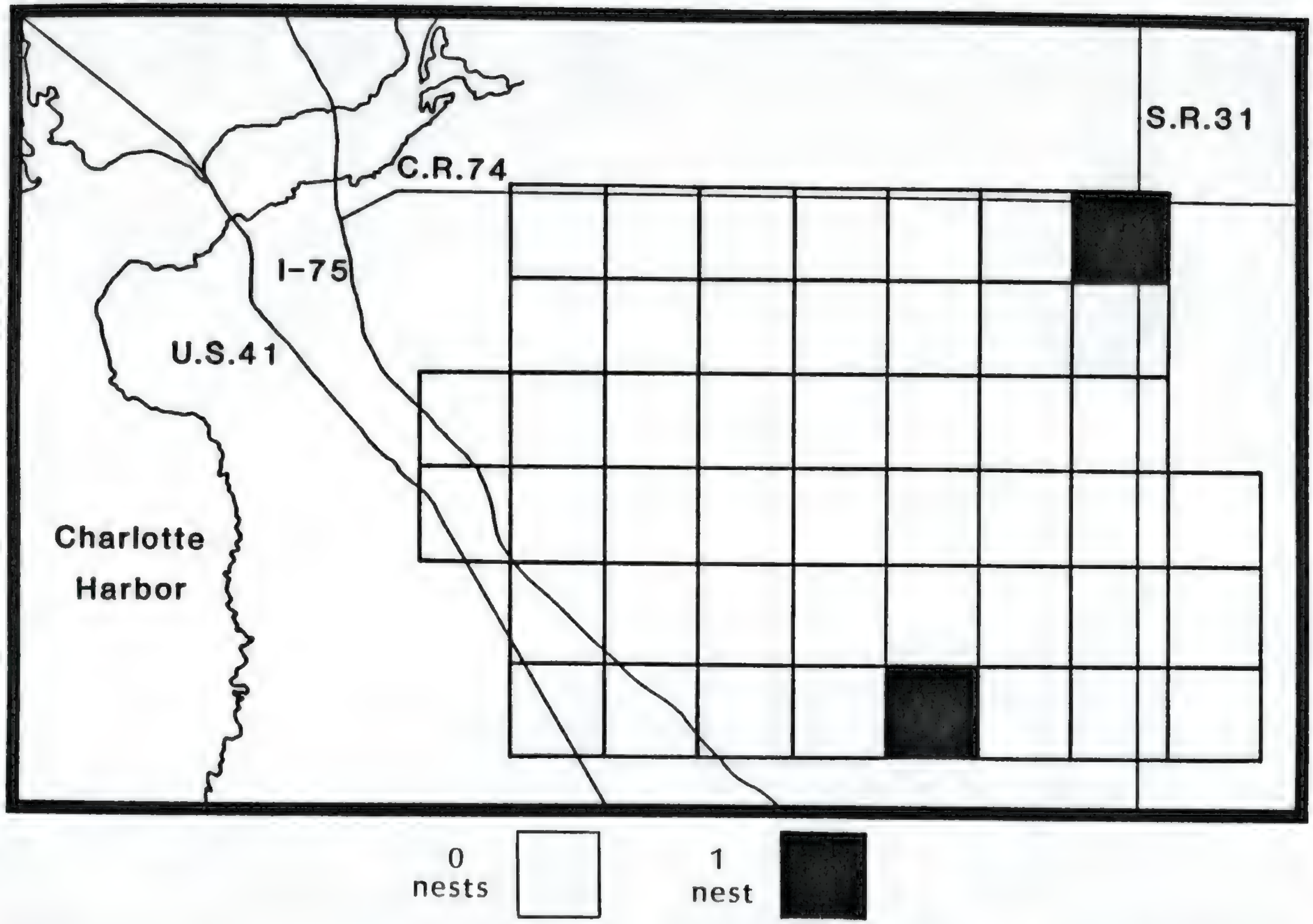

Figure 3-7. Spatial distribution of Florida sandhill crane nests by 3 km x 3 km grid cells observed during 8 systematic aerial transect surveys of the Webb Wildlife Management Area and surrounding lands, January-April, 1985. No repeat sightings are included.

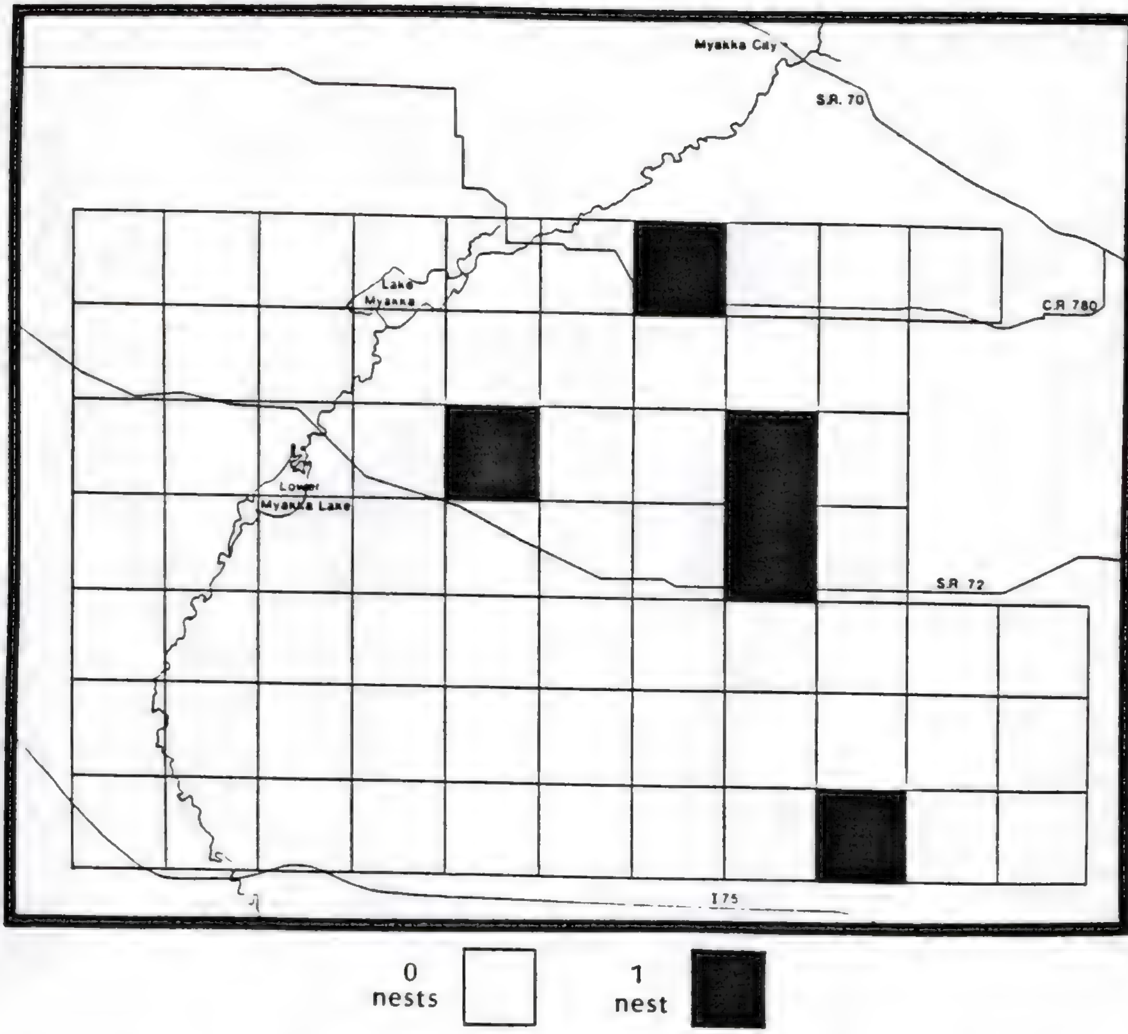

Figure 3-8. Spatial distribution of Florida sandhill crane nests by 3 km x 3 km grid cells observed during 8 systematic aerial transect surveys of Myakka River State Park and surrounding lands, January-May 1985. No repeat sightings are included.

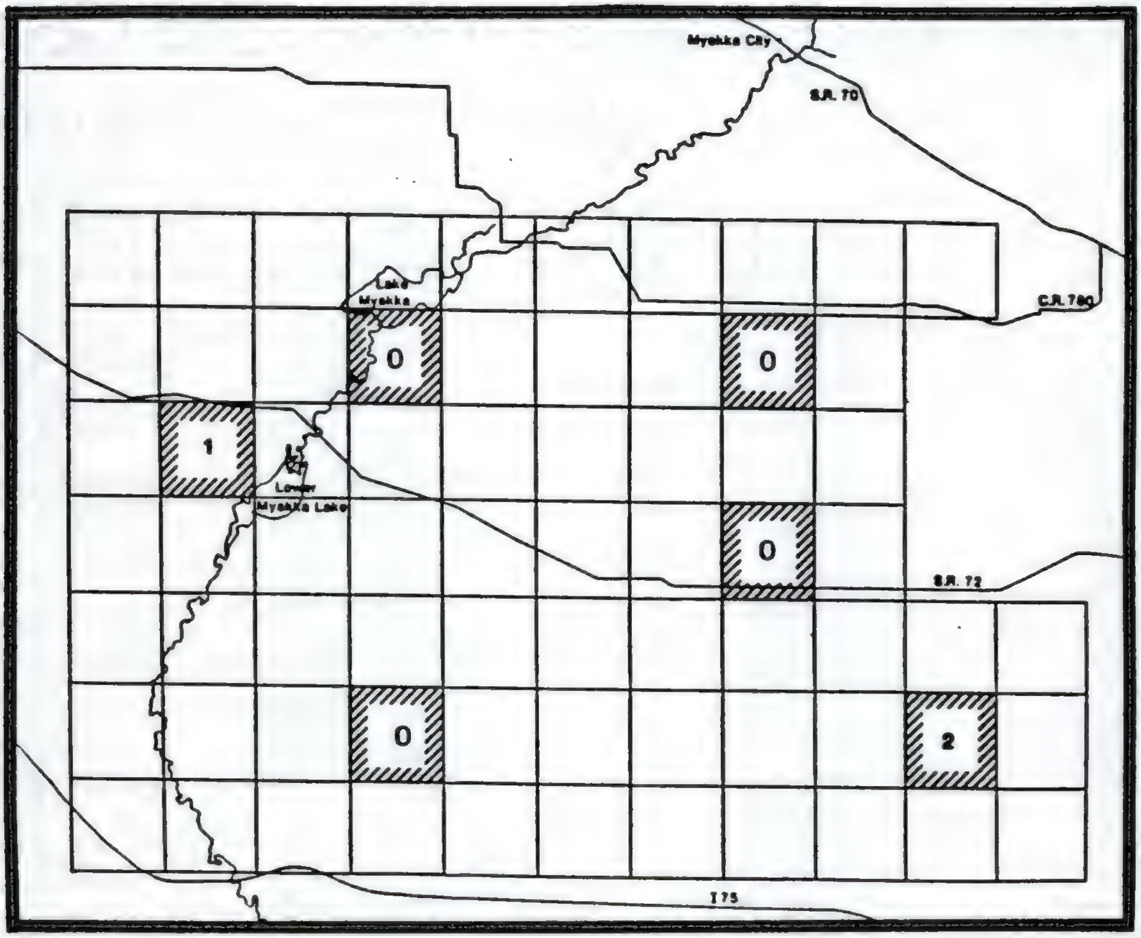

Figure 3-9. Preselected 3 km x 3 km quadrats surveyed for Florida sandhill crane nests during 8 aerial surveys on Myakka River State Park and surrounding lands, January-May 1985. Numbers denote nests sighted.

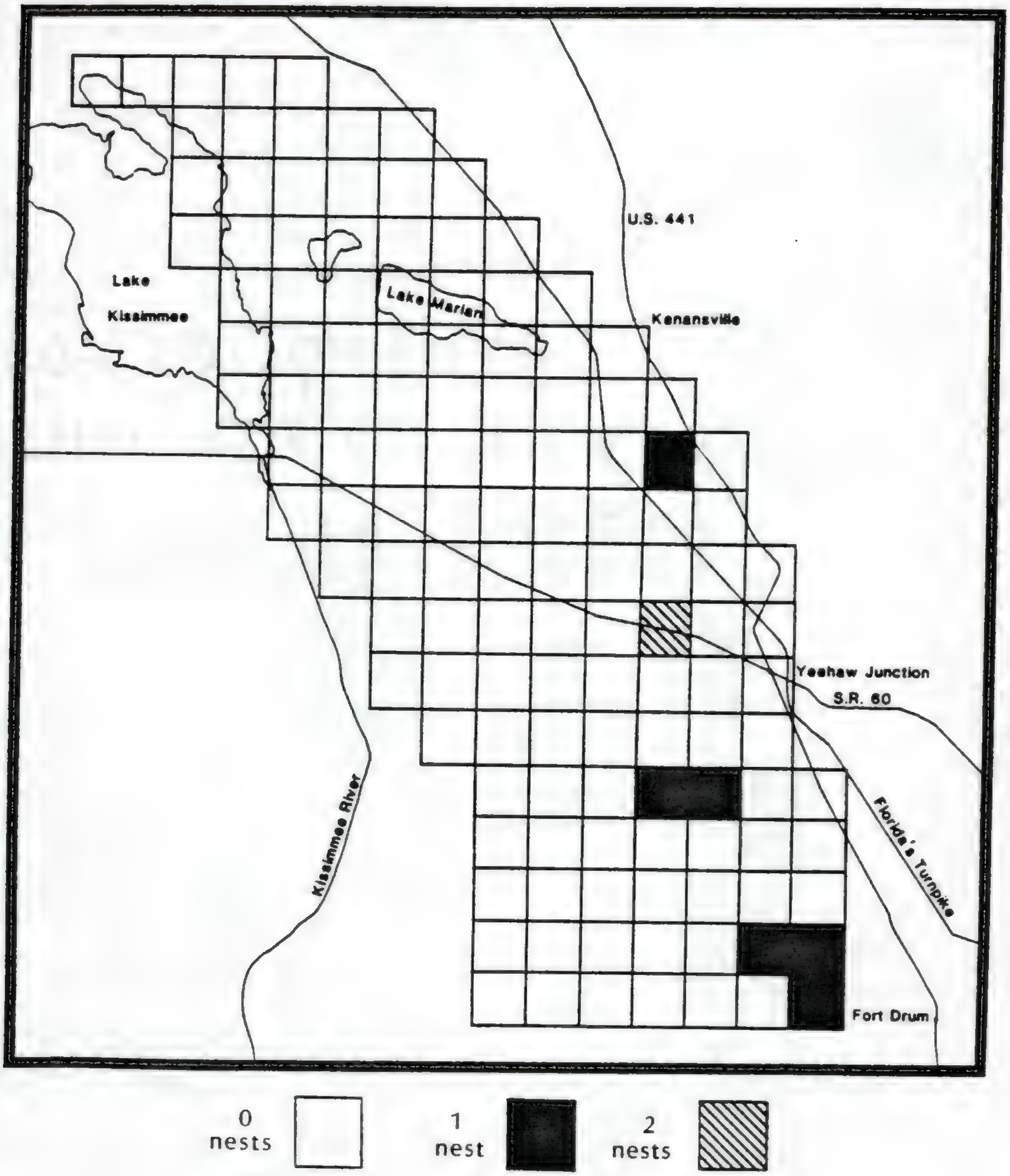

Figure 3-10. Spatial distribution of Florida sandhill crane nests by 3 km x 3 km grid cells observed during 7 systematic aerial transect surveys on the Kissimmee Prairie, Florida, January-May 1985. No repeat sightings are included.

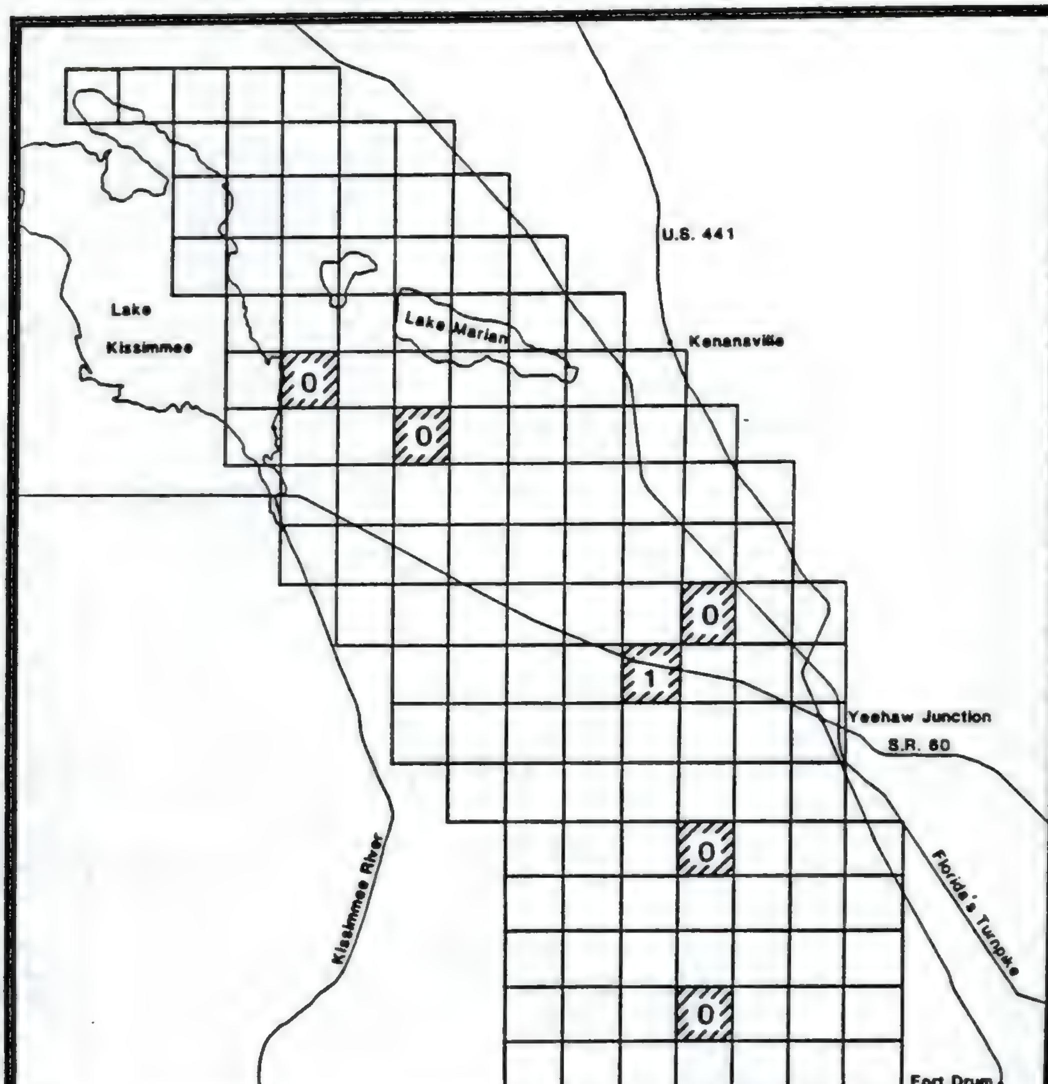

Figure 3-11. Preselected 3 km x 3 km quadrats surveyed for Florida sandhill crane nests during 8 aerial surveys on Kissimmee Prairie, January-May 1985. Numbers denote nests sighted.

In addition to the aerial surveys on the Kissimmee Prairie, ground efforts detected an additional 9 nests, and 9 pairs with prefledged chicks (Appendix C). In all, only 1 nest was located on public lands during this breeding season.

1986 Breeding season. Compared with the 1985 breeding season, nesting attempts in 1986 were substantially more numerous on the transects: nests increased on the Myakka River SP study area from 5 to 27 (Fig. 3-12), on the Webb WMA study area nesting efforts increased from 2 to 38 (Fig. 3-13), and on the Kissimmee Prairie study area from 8 to 54 (Fig. 3-14). Estimated crude densities for the 1986 breeding season ranged from a high of 0.52 breeding pairs/km^2 on the Webb WMA study area to 0.22 breeding pairs/km^2 on Myakka River SP study area (Table 3-4). This increase in nesting attempts is most likely due to better water conditions on all 3 areas throughout the breeding season.

Rainfall for May 1985 through April 1986 continued to be below average on all but the Webb WMA study area (Table 3-5); however, rainfall deficits were not as extreme as during the previous 12 months. For the 6 month dry season, November 1985 through April 1986, both the Kissimmee Prairie and the Webb WMA recorded above average rainfall, +0.8 cm and +0.4 cm, respectively, while the Myakka River SP study area recorded a -6.6 cm departure from normal.

Water levels in groundwater wells on all 3 areas were characterized by weak, interrupted drying trends from January through the end of March. From April through the end of the breeding season, water levels continued to decline steadily on Myakka River SP and the Webb WMA.

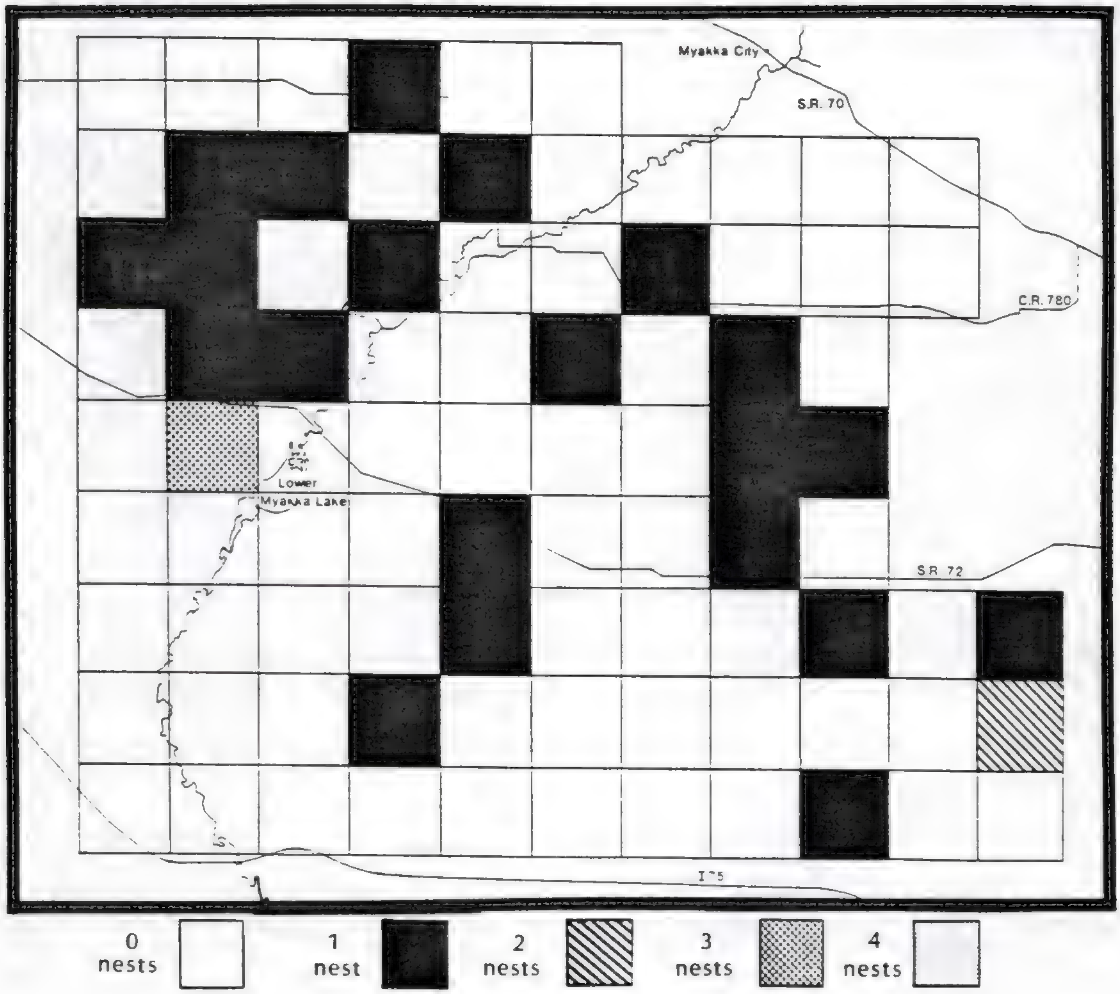

Figure 3-12. Spatial distribution of Florida sandhill crane nests by 3 km x 3 km grid cells observed during 10 systematic aerial transect surveys of Myakka River State Park and surrounding lands, January-May 1986. No repeat sightings are included.

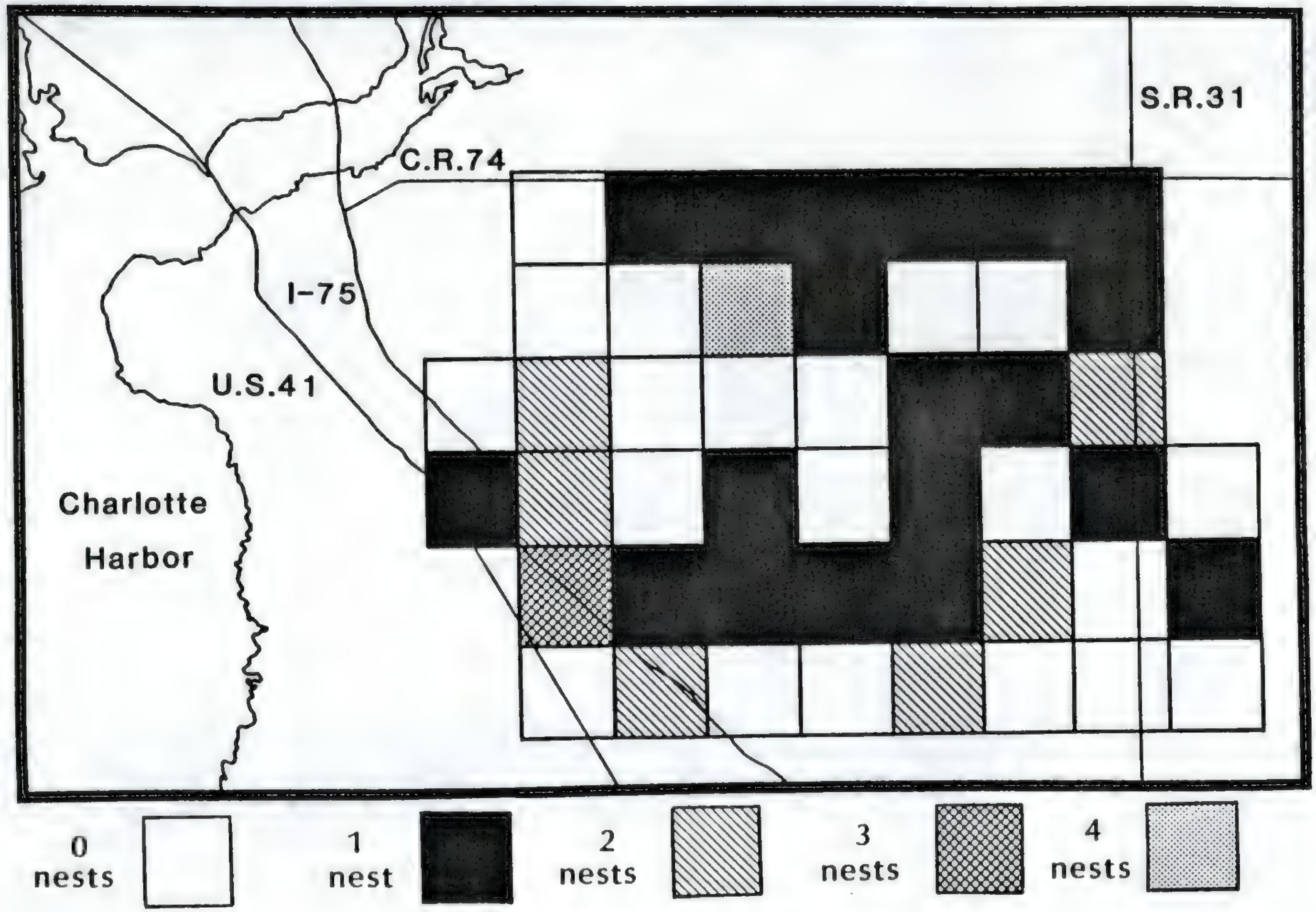

Figure 3-13. Spatial distribution of Florida sandhill crane nests by 3 km x 3 km grid cells observed during 10 systematic aerial transect surveys of Webb Wildlife Management Area and surrounding lands, January-May 1986. No repeat sightings are included.

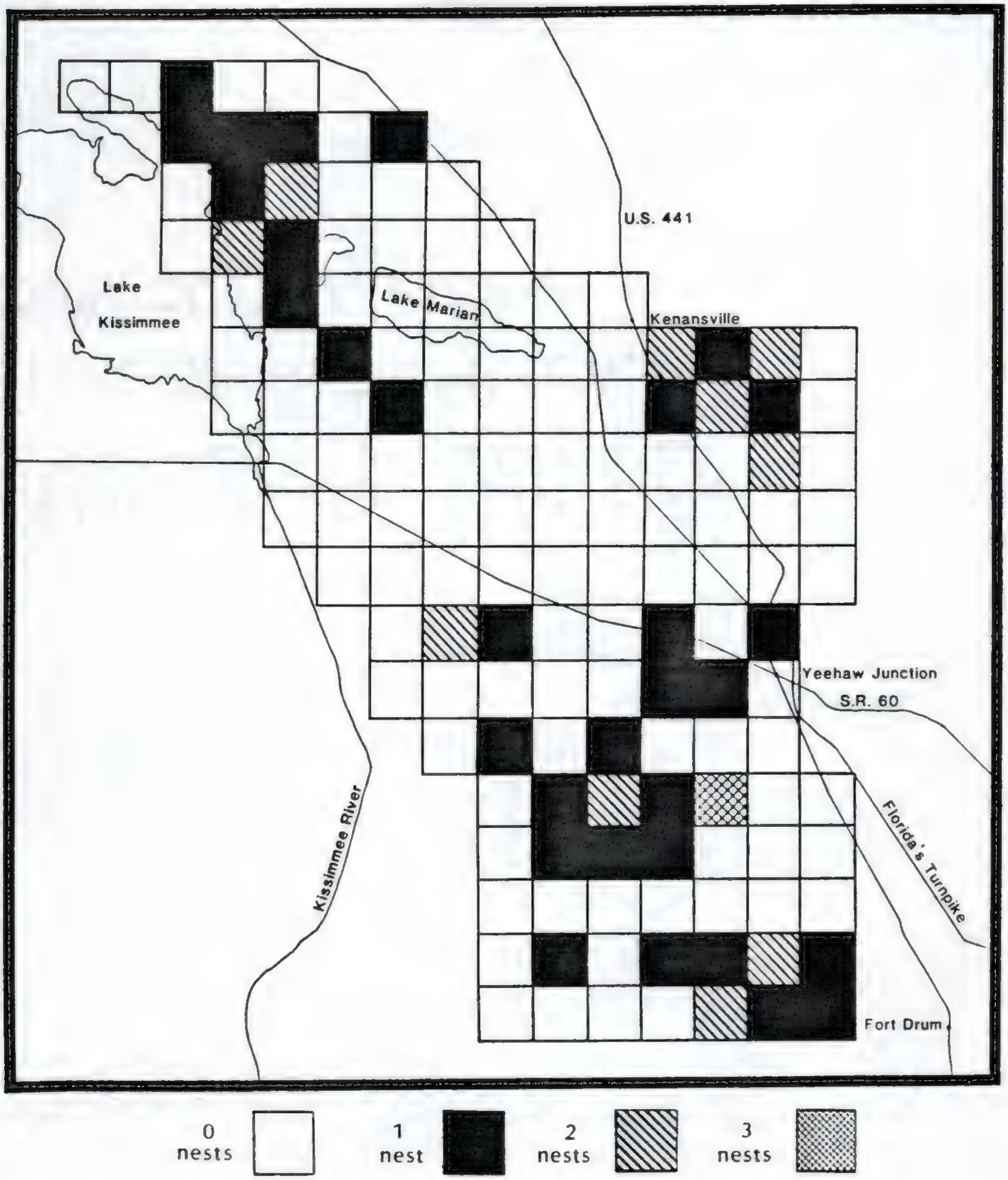

Figure 3-14. Spatial distribution of Florida sandhill crane nests by 3 km x 3 km grid cells observed during 11 systematic aerial transect surveys on the Kissimmee Prairie, Florida, January-May 1986. No repeat sightings are included.

Table 3-5. Total precipitation and departure from normal (cm) on 3 study areas in central Florida for 1 May 1985 - 30 April 1986.

	Kissimmee Prairie[a]		Myakka River SP[b]		Webb WMA[c]	
Month/yr	Precip	Depart	Precip	Depart	Precip	Depart
May 1985	8.8	-4.6	0.6	-9.2	9.5	-0.7
Jun 1985	18.3	-2.1	14.2	-7.0	29.9	10.1
Jul 1985	17.1	-2.7	19.0	-2.4	17.1	-0.6
Aug 1985	15.0	-1.6	23.1	-0.7	17.7	-1.4
Sep 1985	10.6	-5.5	24.4	2.6	13.9	-5.2
Oct 1985	3.2	-5.4	4.9	-3.7	7.1	-2.4
Nov 1985	7.6	2.6	7.8	2.4	9.4	5.4
Dec 1985	4.3	-0.9	1.0	-4.5	6.1	1.5
Jan 1986	6.3	0.7	4.6	-1.9	1.4	-4.0
Feb 1986	3.9	-3.4	4.2	-3.6	3.0	-2.9
Mar 1986	13.1	6.4	11.2	4.0	9.9	3.9
Apr 1986	0.8	-4.6	2.5	-3.0	1.0	-3.5
Total	109.0	-21.1	117.5	-27.0	126.0	0.2

[a] Calculated from S-65 dock at south end of Lake Kissimmee, South Florida Water Manage. District, unpubl. data 1986.
[b] U.S. Dep. Comm. 1985, 1986.
[c] U.S. Dep. Comm. 1985, 1986 and Webb WMA files.

The earliest successful nesting attempt on the Webb WMA study site was initiated in late December 1985 (H. Anderson, FGFWFC, pers. commun., 1986). The last nesting attempt was recorded on the 8 May flight. For 1986, peak nesting occurred on 12 March, approximately the same time as the 1984 nesting season (Table 3-2, Fig. 3-6). Of 47 nests located on the ground and from the air, 74% (35) were located within the Webb WMA property boundaries, and 2% (1) on Charlotte County Airport (Appendix C).

At Myakka River SP study area the 1986 peak nest density was recorded on 12 April (Fig. 3-5). During 9 fixed-wing and 1 helicopter survey, a total of 43 nests were observed. These included 27 transect nests (Fig. 3-12) and 16 nests incidentally observed. An additional 3 families with prefledged chicks were located through ground efforts (R. Dye, FDNR, pers. commun., 1986) (Appendix C). Fifteen percent of the nests and family groups (7) were located on public lands, including 11% (5) within Myakka River SP.

During 1986 aerial nesting surveys on the Kissimmee Prairie, 59 nests initially were located on regular transects during 9 fixed-wing surveys and 2 helicopter surveys. This total was reduced to 54 transect nests (Fig. 3-14), after ground-truthing failed to adequately confirm 5 nests. Another 35 nests were located incidentally from the air for a total of 89 nests. In addition to these 89 nests, 22 nests and 26 pairs with prefledged chicks were located from ground efforts for a total of 137 known nesting attempts. Of the 137 nests and/or pairs with prefledged chicks, 8.2% (11) nests were on state lands, 1.5% (2) on the NAS Kissimmee Prairie Sanctuary, and the remainder on private lands (Appendix C).

The earliest known successful nesting attempt was initiated the first week of January in Osceola County, and the latest laying date recorded was approximately 18 May in Osceola County. When only aerial transect densities are considered, the estimated peak nesting density was 17 February 1986 (Fig. 3-4). This date is approximately 1 month earlier than the 1984 and 1985 nesting peaks for the area and is earlier than both the Webb WMA and Myakka River SP study areas by 1 and 2 months, respectively (Table 3-2).

Population Estimates and Confidence Limits

When population estimates and 95% confidence limits were determined for all 1984-1986 fixed-wing surveys, over one-half of the lower confidence limits included zero or a negative number (Tables 3-6, 3-7, 3-8). The large variances in the population estimates for each survey are a result of the small number of transects sampled relative to the census areas, the low numbers of nests counted per flight, and the variability in the distribution of nests within each study area.

Because exact locations of nests could not be determined for the 1984 surveys, an estimated total breeding pair population for that season could not be determined. For the 1985 season, the estimated breeding population based on the total number of unique nests counted on all transect surveys was 12 $\pm$ 19 pairs on the Webb WMA, 31 $\pm$ 30 pairs on Myakka River SP, and 49 + 40 pairs on the Kissimmee Prairie. In 1986, all 3 areas had much higher population estimates 211 $\pm$ 62 pairs on the Webb, 150 $\pm$ 60 pairs on Myakka River State Park, and 300 $\pm$ 111 pairs on the Kissimmee Prairie (Table 3-4). When the confidence limits are expressed as a percentage of the estimated breeding pair

Table 3-6. Estimated breeding pairs ($\hat{Y}$) and 95% confidence intervals (CI) determined from aerial fixed-strip transects surveys at 3 areas in central Florida, Spring 1984.

Date	Transects surveyed	Nests	$\hat{Y} \pm$ 95% CI
Webb WMA			
9 Mar	10	14	60 ± 32
26 Mar	12	6	23 ± 22
17 Apr	10	7	32 ± 31
30 Apr	10	6	29 ± 20
14 May	10	2	9 ± 12
Myakka River SP			
9 Mar	10	11	61 ± 35
26 Mar	12	8	37 ± 20
17 Apr	11	3	15 ± 15
14 May	7	2	15 ± 21
Kissimmee Prairie			
1 Mar	16	9	79 ± 46
10 Mar	24	31	178 ± 74
2 Apr	26	14	75 ± 40
16 Apr	26	3	16 ± 17
7 May	24	1	6 ± 11

Table 3-7. Comparison of estimated breeding pairs ($\hat{Y}$) and 95% confidence intervals (CI) determined from aerial fixed-strip transects with estimates from intensive aerial searches of 3 km x 3 km quadrats at 3 areas in central Florida, Spring 1985.

	Transects			Quadrats		
Date	N	Nests	$\hat{Y} \pm$ 95% CI	N	Nests	$\hat{Y} \pm$ 95% CI
Webb WMA						
23 Jan	6	0	0	-	-	-
4 Feb	6	0	0	-	-	-
26 Feb	6	0	0	3	0	0
11 Mar	6	0	0	3	0	0
19 Mar	6	1	8 $\pm$ 21	4	0	0
5 Apr	6	1	8 $\pm$ 20	6	0	0
17 Apr	6	0	0	4	0	0
29 Apr	6	0	0	4	0	0
Myakka River SP						
23 Jan	7	0	0	-	-	-
26 Feb	7	0	0	3	0	0
11 Mar	7	0	0	3	1	21 $\pm$ 90
19 Mar	7	0	0	3	0	0
5 Apr	6	0	0	6	1	11 $\pm$ 26
17 Apr	7	3	25 $\pm$ 27	3	1	21 $\pm$ 90
29 Apr	7	4	33 $\pm$ 41	3	0[a]	0
9 May	7	2	17 $\pm$ 26	2	0	0
Kissimmee Prairie						
29 Jan	18	1	8 $\pm$ 17	-	-	-
18 Feb	18	2	17 $\pm$ 33	3	0	0
4 Mar	18	2	17 $\pm$ 33	3	0[a]	0

Table 3-7.---continued.

	Transects			Quadrats		
Date	N	Nests	$\hat{Y} \pm$ 95% CI	N	Nests	$\hat{Y} \pm$ 95% CI
14 Mar	17	4	35 ± 40	3	1	39 ± 166
9 Apr	17	1	9 ± 18	3	0	0
24 Apr	18	2	17 ± 23	3	0	0
6 May	18	0	0	3	0	0

[a] Known nest was not detected.

Table 3-8. Estimated breeding pairs ($\hat{Y}$) and 95% confidence intervals (CI) determined from aerial fixed-strip transects surveys at 3 areas in central Florida, Spring 1986.

Date	Transects surveyed	Nests	$\hat{Y} \pm$ 95% CI
Webb WMA			
15 Jan	6	2	15 ± 24
29 Jan	6	2	15 ± 23
12 Feb	6	10	75 ± 21
26 Feb	6	6	45 ± 38
12 Mar	6	11	83 ± 71
26 Mar	6	3	23 ± 24
12 Apr	6	2	15 ± 23
23 Apr	6	3	23 ± 38
8 May	6	1	8 ± 18
Myakka River SP			
15 Jan	8	1	8 ± 19
29 Jan	8	3	24 ± 29
12 Feb	9	2	15 ± 32
26 Feb	9	5	38 ± 23
12 Mar	9	6	45 ± 29
26 Mar	9	3	23 ± 25
12 Apr	9	8	60 ± 34
22 Apr	9	7	53 ± 49
8 May	9	0	0

Table 3-8.---continued.

Date	Transects surveyed	Nests	$\hat{Y} \pm$ 95% CI
Kissimmee Prairie			
21 Jan	18	2	15 ± 20
4 Feb	18	7	53 ± 44
17 Feb	18	27	203 ± 94
3 Mar	18	19	143 ± 70
24 Mar	24[a]	9	59 ± 34
1 Apr	23[a]	8	53 ± 32
15 Apr	18	4	30 ± 34
29 Apr	18	4	30 ± 29
15 May	17	1	10 ± 16

[a] Includes extra transects flown over Three Lakes WMA.

population, in 1985, confidence limits ranged from 82 to 158% of the estimated breeding population, whereas in 1986, confidence limits ranged from 29 to 40% of the estimated breeding pair population.

Transect Repeatability Between Flights

All fixed-wing aircraft were equipped with an Apollo II LORAN (Long Range Navigation)-C receiver for fixed-strip surveys during 1985 and 1986. The Jet Ranger 206-BIII helicopter used on 4 occasions in 1986 (see section below on nest detectability) contained an Arnav LORAN-C receiver. Transect repeatability for the season was measured by nest resightings. For the 3 areas, nest resightings ranged from 25 to 60% of all transect nests (Table 3-9). For 1985, all resightings occurred on the following survey, 10-20 days later.

In 1986, 6 of 8 nest resightings on Myakka River SP study area occurred on the following survey (10 to 14 days later), 6 of 11 resightings on the Webb WMA study area occurred on the following survey (11 to 14 days later), and 19 of 19 resightings on the Kissimmee Prairie occurred on the following survey (13 to 21 days later). The longest interval between the initial sighting and a final sighting was 60 days on the Webb WMA (4 flights), 70 days on the Kissimmee Prairie (5 flights later), and 37 days on Myakka River SP (5 flights later).

Bias in Aerial Surveys

There are 2 sources of error in any census estimate: sampling error and bias. A sampling error changes from 1 observation to the next but tends towards zero. A bias systematically distorts an estimate in the same or similar sampling units (Jolly 1969b). Bias in

Table 3-9. Percent of nests on aerial transects observed during more than one flight, 1985 and 1986 breeding surveys.

	1985		1986	
Area	Total nests	% Nests resighted	Total nests	% Nests resighted
Webb WMA	2	0	38	29
Myakka River SP	5	60	27	30
Kissimmee Prairie	8	25	54	35

aerial sampling can be due to various causes including the census design, implementation, and analysis.

Quadrat estimates compared to fixed-strip estimates. In order to test census design effects on results, in 1985 I compared quadrat estimates with fixed-strip estimates. I surveyed each area using both fixed-strip transects and preselected 3 km x 3 km quadrats. Despite efforts to mark quadrat boundaries with orange day-glow plastic squares, quadrats proved both difficult to locate and difficult to search without missing some areas. At the same time, for all 3 study areas the 1985 season was characterized by a severe drought and very few nesting attempts.

The lower 95% confidence limits for all survey population estimates during 1985 included 0 or a negative number when using quadrat or fixed-strip transect methods (Table 3-7). On the Webb WMA area, no nests were found in quadrats during the 6 fixed-wing surveys. One quadrat-nest was found during 6 quadrat surveys on the Kissimmee Prairie (Fig. 3-11). and 1 quadrat-nest was known from ground efforts, but not located from the air. On Myakka River SP area, 2 nests were detected on 3 occasions in quadrats (Fig. 3-9, Table 3-7), and another was known from transects but not located during the quadrat search.

Front and back seat observer differences. During census implementation, there are several potential sources of bias including observer error. For each survey area I compared the 1985 and 1986 season breeding pair estimates and 95% confidence intervals for the front seat observer (myself) and the back seat observer. Estimates were based on the first-time sighting of a transect nest.

The seasonal population estimates were similar between observers for the Webb WMA and Myakka River SP in 1985, and for the Webb WMA in 1986 (Table 3-10). For all six 1985 and 1986 seasonal breeding pair estimates, confidence intervals overlapped indicating no significant differences between observers.

As pointed out earlier, the ratio-estimation procedure tends to produce large confidence intervals, especially when there are small numbers of sampled transects, few nests, and an uneven distribution. As an example of how this effects confidence intervals, for 1986 on the Webb WMA, the front seat observer sighted 20 nests, and the back seat observer 18 nests. While the estimated population was similar for both observers (222 and 200 breeding pairs) the confidence interval for the back seat observer was more than 2 times that of the front seat observer (± 119 versus ±54 breeding pairs). This difference was due to the variability in the distribution of the sightings between transects.

Effect of flight speed on nest detectability. Other potential sources of bias during census implementation include navigation and orientation and their effects on detectability. Caughley (1974) examined in detail the 3 factors that effect sightability (detectability), that is, the probability that an animal within an observer's field of search will be seen. These factors include strip width, altitude, and speed. An increasing strip width can potentially introduce a negative bias on the probability of detectability, whereas an increasing altitude can potentially produce either a negative or a positive bias. Increased speed potentially introduces 2 negative biases on detectability because: (1) the time available to locate and

Table 3-10. Seasonal Florida sandhill crane breeding pair population estimate ($\hat{Y}$) and ±95% confidence interval (CI) based on initial transect nest sighting for front seat and back seat observers.

		Front Observer		Back Observer	
Area	Year	N	$\hat{Y}$ ± 95% CI	N	$\hat{Y}$ ± 95% CI
Webb	1985	1	14 ± 35	1	11 ± 28
	1986	20	222 ± 54	18	200 ± 119
Myakka	1985	2	28 ± 44	3	33 ± 38
	1986	17	189 ± 91	10	111 ± 74
Kissimmee	1985	7	97 ± 92	1	11 ± 23
	1986	21	233 ± 126	33	367 ± 153

count animals decreases; and, (2) the required rate of eye movements increases.

In 1985 and 1986, I tested how flight speed effects nest detectability for each area by comparing results of helicopter surveys with results obtained 1-3 days earlier from fixed-wing aircraft surveys. For 1985, a comparison of results from quadrat surveys were not conclusive (Table 3-11). On the Webb WMA, no nests were found on either survey. On Myakka River SP, the 1 nest located during the fixed-wing survey was no longer active on the helicopter survey 3 days later. At the same time, 2 nests were located that had not been detected from the fixed-wing. The helicopter used to survey quadrats on the Kissimmee Prairie did not have a LORAN-C receiver, and quadrats were difficult to locate. The 1 nest seen during the fixed-wing quadrat survey 3 days earlier, however, was resighted.

On 4 occasions in 1986, 6 fixed-strip transects flown the previous day in a fixed-wing aircraft were repeated by helicopter using the same methods described previously for all fixed-strip transects. On both the Kissimmee Prairie and the Webb WMA, there was an increase in the number of nests sighted (Tables 3-12, 3-13). On Myakka River SP, however, the number of nests sighted decreased from 3 to 0.

Differences between the surveys can in part be explained by pilots and problems associated with transect repeatability. For the Webb WMA and Myakka River SP surveys, the fixed-wing surveys were flown the previous day by a pilot who had never flown the surveys. While the 4 helicopter flights were flown by 1 pilot, this same pilot had not flown any of the earlier fixed-wing surveys.

Table 3-11. Comparison of nests sighted and estimated breeding pair population ($\hat{Y}$) and 95% confidence intervals determined from fixed-wing aircraft and helicopter surveys of six 3 km x 3 km quadrats for each study area during 1985.

	Fixed-wing			Helicopter			
	Quads surveyed	Nests	$\hat{Y} \pm 95\%$	Quads surveyed	Nests	$\hat{Y} \pm 95\%$	Days Apart
Webb WMA	6	0	0	6	0	0	3
Myakka River SP	6	1	11 ± 26	6	2[a]	21 ± 33	3
Kissimmee Prairie	3	1	39 ± 166	6	1	20 ± 49	3

[a] Nest seen previously no longer active.

Table 3-12. Comparison of nests sighted on 6 fixed-strip transects from a fixed-wing aircraft with nests sighted from a helicopter the following day, Kissimmee Prairie, 1986.

	4-5 February		1-2 April	
Transect	Fixed-wing	Helicopter	Fixed-wing	Helicopter
1	0	0	1	1
2	0	0	1	1
3	0	0	1	1
4	2	1[a]	1	1
5	0	2	0	1
6	1	1	0	0
Total Nests	3	4	4	5

[a] Nest from previous day missed because transect starting point was different.

Table 3-13. Comparison of nests sighted on 6 fixed-strip transects from a fixed-wing aircraft on 29 January, 1986 with nests sighted from a helicopter the following day, Myakka River SP and Webb WMA.

	Myakka River SP		Webb WMA	
Transect	Fixed-wing	Helicopter	Fixed-wing	Helicopter
1	1	0	1	0
2	1	0	0	3
3	1	0	0	0
4	0	0	1	0
5	0	0	0	2[a]
6	0	0	0	1
Total Nests	3	0	2	6

[a] Transect latitude different from previous day.

In addition, both aircraft were equipped with different LORAN-C receivers. The Apollo LORAN-C receiver used in the fixed-wing aircraft, calculates latitude to 0.01 minutes (20 m). The Jet Ranger helicopter I used contained an Arnav LORAN-C receiver that calculates latitudes within 0.10 minutes (200 m) and could not be recalibrated for the known fixed spot, forcing me to readjust all of the flight-line latitudes. In addition, the 200 m strip seen from the helicopter, was not at the same angle as that set for the observers in the fixed-wing aircraft.

Environmental Correlates of Nesting Densities

The average maximum daily water levels in groundwater wells for the 7, 14, and 30 days prior to the survey were positively correlated ($P < 0.0001$) with nesting densities (Appendix D). Correlations were then determined for nesting densities and daily maximum water levels for each of the 30 days prior to the aerial nesting surveys. Significant correlations were shown for all maximum daily groundwater well levels during the 30 days prior to the surveys (Appendix D). Two other environmental variables related to water levels: the total rainfall during the 30 days prior to the flight ($r = 0.35$, $P < 0.004$), and the average drying/rising rate in water levels 30 days prior to the flight ($r = 0.25$, $P < 0.04$) also were significantly correlated to nesting densities (Appendix D) suggesting that wetland conditions do affect nest initiation.

The only temperature variable that showed a significant, negative correlation to nesting densities was the average maximum temperature for 7 days prior to the flight ($r = -0.29$, $P < 0.017$). Photoperiod, represented by the Julian date, did not show a significant linear correlation to nesting densities (r = -0.04, P < 0.72).

A stepwise multiple regression was used to examine predictive relationships between the nesting densities and environmental variables. All environmental variables listed in Appendix D-1 were used in the analysis. Four variables were found to be significant at the 0.15 level, and were included in the model.

The fitted regression was of the form:

$$\underset{(0.048263)}{Y = -0.02195} + \underset{(0.000942)}{0.00307X_1} - \underset{(0.001860)}{0.00365X_2} + \underset{(0.021775)}{0.06777X_3} - \underset{(4 * 10^{-6})}{1.464\text{x}10^{-4}X_4}$$

MSE = 0.4445, R^2=0.3486.

In this regression, Y = nesting densities, X_1 = Julian date (photoperiod), X_2 = the total rainfall for the previous 30 days, X_3 = average groundwater well water depth 14 days prior to the flight, and X_4 = the quadratic form of the Julian date (i.e. photoperiod^2), and standard errors of the parameter estimates are given in parentheses below the formula.

Among the independent variables there were positive significant correlations between Julian date and quadratic form of the Julian date (r = 1.0,), Julian date and the total 30-day rainfall (r = 0.28, P < 0.027), total 30-day rainfall and the average water depth 14 days prior to the flight (r = 0.46, P < .0002), and total 30-day rainfall and the quadratic form of the Julian date (r = 0.28, P < 0.0265). The effect of colinearity could cause the standard error of the model's estimate to be smaller than it should be. The R^2 for the model is so low, however, that it is unlikely that the removal of these effects would change the overall conclusion of the model.

Nest Site Characteristics and Evidence of Hatch Success

Wetland characteristics. Using the wetland system developed by Cowardin et al. (1979) 3 wetland systems were identified on the 3 study areas: lacustrine, palustrine, and riverine. On Myakka River SP and the Kissimmee Prairie, all 3 wetland systems were available, whereas on the Webb WMA study area only lacustrine and palustrine were available.

On all 3 areas, cranes nested almost exclusively in palustrine emergent wetlands. These include nontidal wetlands dominated by persistent and nonpersistent emergents such as maidencane (*Panicum hemitomon*), pickerelweed (*Pontederia cordata*), sedges (*Carex* spp.), and arrowheads (*Sagittaria* spp.). At Myakka River SP study site during both 1985 (N = 14) and 1986 (N = 41), 95% of the nests located were in palustrine emergent wetlands. Of the nests located on the Webb WMA study site in 1985 and 1986, 80% (N = 5) and 100% (N = 46) were located in palustrine emergent wetlands, respectively. On the Kissimmee Prairie 97% (N = 29) of the nests located in 1985, and approximately 98% (N = 111) of the nests located in 1986 were in palustrine emergent wetlands. Stock ponds with emergent vegetation were used as nest ponds once on the Myakka River SP study site and twice on the Kissimmee Prairie study site. In addition, 2 nests were located in ditches on the Kissimmee Prairie. Of the other 2 wetland systems, 1 nest was found on the Myakka River in 1985 (H. Jelks, pers. commun., 1985), and 1 nest was found in Lake Kissimmee in 1985.

There was evidence of nesting in the same wetland between years. Of all wetlands identified with nests in 1985, 23% (3) on Myakka River SP area, 66% (2) on the Webb WMA area, and 43% (10) on the Kissimmee Prairie contained nests again in 1986. I also found simultaneous nesting in the same wetland. On the Kissimmee Prairie, ground efforts located simultaneous nesting attempts in 3 of the 23 identified nest wetlands in 1985 (2 nests in each), and in 3 of the 106 nest wetlands located in 1986 (2 nests each for 2 wetlands, and 4 nests in 1 wetland). These multiple nest wetlands ranged in size from 5.46 to 51.13 ha.

Average size of the nest wetlands varied between years on study areas (Table 3-14). In 1985, drought conditions on all 3 areas caused many wetlands to be dry throughout the nesting season. On both Myakka River SP and the Kissimmee Prairie, a larger proportion of the nests occurred in wetlands >10 ha in 1985 than in the following year (Fig. 3-15). The lack of suitable nest sites during a drought may be exacerbated by a shortened hydroperiod resulting from ditching. On Myakka River SP and the Kissimmee Prairie from 44 to 62% of nest wetlands during a season were ditched. On the Webb WMA study area where most of the nests occurred on the WMA, only 12% of the nest wetlands were ditched (Table 3-14).

Surrounding habitat characteristics. Nesting cranes are apparently tolerant of small amounts of vehicular traffic. Of the 225 nest wetlands identified on all 3 areas, 21% bordered dirt roads, and 3% bordered state and county roads. Very few nests, however, were close to areas with human activity such as buildings, barns, and orange groves. Over 54% of the nest wetlands were located over 3 km from any human activity. The 2 nests closest to human activity included the 1 nest found on Lake Kissimmee, which occurred within 5 m of an airboat trail and a nest in a wetland bordering an orange grove.

Table 3-14. Average size, range, and proportion ditched of the nest wetlands (ha) in which Florida sandhill cranes nested for 3 areas in central Florida.

Area	Year	N	Mean (ha)	Range (ha)	% Ditched
Webb WMA					
	1985	3	12.2	2.5 - 17.9	0
	1986	46	30.0	1.2 - 424.2	13
Myakka River SP					
	1985	12[a]	8.5	0.75 - 36.7	62
	1986	41	11.0	0.85 - 216.7	61
Kissimmee Prairie					
	1985	26[b]	15.2	0.97 - 51.1	61
	1986	95	10.4	0.46 - 53.5	44

[a]Does not include nest found on Myakka River.
[b]Does not include nest found on Lake Kissimmee.

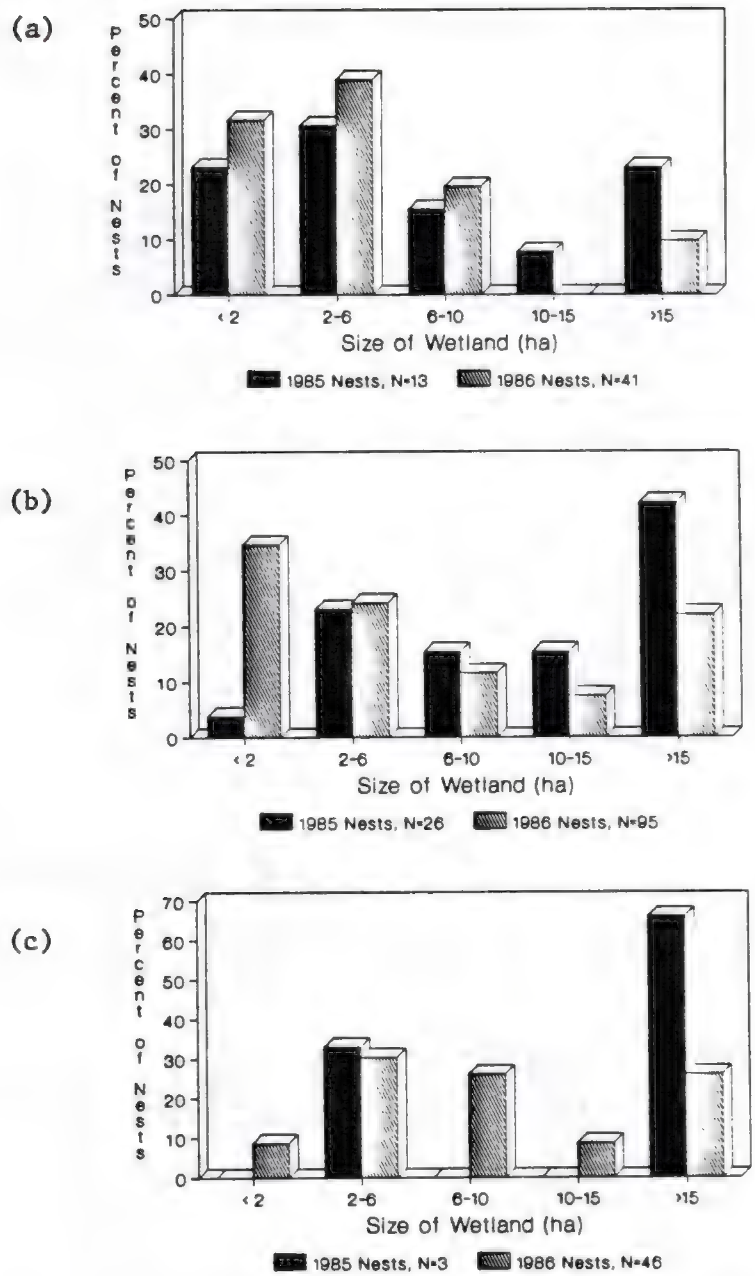

Figure 3-15. Size of wetland (ha) used by Florida sandhill cranes for nesting during 1985 and 1986. (a) Myakka River State Park and surrounding lands. (b) Kissimmee Prairie. (c) Webb Wildlife Management Area and surrounding lands.

On all 3 areas, cranes primarily selected wetlands with adjoining open, upland habitat. On the Kissimmee Prairie and Myakka River SP area, over 50% of the nest wetlands during both 1985 and 1986 bordered improved pastures. On the Webb WMA only 2% of the management area is improved pastures (FDOT 1978); however, almost 9% (4) of the 46 nest wetlands were located adjoining this habitat.

Ownership status. To evaluate potential impact on future Florida sandhill crane nesting habitat, I identified 5 ownership/land use categories where nest wetlands or prefledged chicks had been identified. These included small landowner (<800 ha), private industry, cattle ranch (>800 ha), commercial development, and public lands. On the Kissimmee Prairie, cranes nested primarily on the large cattle ranches (78%). While public lands accounted for approximately 15% of the survey area, approximately 8% of the nests were located on these lands (Table 3-15).

On Myakka River SP study area, cranes also nested primarily on the large cattle ranches (50%), although another 17% of the nests occurred on small landowner properties. Approximately 22% of the nests occurred on public lands, which accounted for 31% of the survey area. While the Webb WMA composed 65% of the total survey area, 76% of the nests were located on these public lands (Appendix C).

On-site nest visits. On the Kissimmee Prairie, 74 nests sites located in 69 wetlands were visited, including 42 of the 57 transect nest wetlands (Table 3-16). Hatch success, as evidenced by eggshell fragments was determined not to be a reliable method in determining nesting success. At 5 nests visited, no eggshell fragments were located but chicks were seen in the immediate vicinity. This may have

Table 3-15. Percent ownership status of Florida sandhill crane nest wetlands for 3 areas in central Florida based on nest and flightless-chick sightings, 1985 and 1986.

Area	N	Small landowner	Private industry	Cattle ranch	Comm develop	Public lands[a]
Webb WMA	50	6.0	0	14.0	4.0	76.0
Myakka River	58	17.2	8.6	50.0	1.7	22.4
Kissimmee Prairie	155	11.0	1.6	78.0	1.0	8.4

[a] Includes National Audubon Society Kissimmee Prairie Sanctuary.

Table 13-16. Outcome of visits to nest wetlands on Kissimmee Prairie, Spring 1986.

Method	Observed	Ground Truthed	Located	Incubating	Fragments	Chick	No Fragments
On aerial transect	57[a]	42	6	4[b]	16[b]	10	6
Off aerial transect	32	13	3	2	7	1	0
Ground	22[b]	19	-	1	6[c]	10	3[b]
Total nests	111	74[d]	9	7	30	21	9

[a] Includes 3 nests sighted on extra transects flown 24 March and 1 April.
[b] Includes 1 renest.
[c] Includes outcome of 2 initial and renest attempt.
[d] 69 nest wetlands.

been due to the scattering of fragments in a loose substrate, especially after rain, or the result of mistakenly locating an accessory nest instead of the actual nest. Similarly, relying on eggshell fragments as an indication of nest success, masked the possibility of infertile eggs being broken by pairs.

Brood Size and Annual Juvenile Recruitment

Mean brood sizes observed during the 1984 fall road counts (Table 3-17) were 1.16 on both the Myakka River SP and the Kissimmee Prairie study areas, and 1.24 on the Webb WMA. Frequency of juveniles/100 adult-plumaged cranes ranged from a low of 6.0 on the Webb WMA to a high of 11.2 on the Kissimmee Prairie (Table 3-17). My fall surveys during 1984 probably underestimated juvenile recruitment because of a lack of familiarization of the study areas. In particular, on the Webb WMA, frequency of juveniles/100 adults probably was low due to limited access to the area. Flooded roads and terrain conditions were such that no cranes were counted on the management area, despite 36 nests recorded during the breeding season.

Brood sizes observed during the 1985 fall road counts averaged 1.2 on the Webb WMA and Kissimmee Prairie study areas, and 1.14 on the Myakka River SP study area. Frequency of juveniles/100 adult-cranes ranged from a low of 7.0 on the Webb WMA to a high of 9.9 on the Kissimmee Prairie (Table 3-17).

For all 3 years, brood sizes and juvenile recruitment rates were highest for the 1986 fall road counts. Mean brood sizes observed ranged from 1.28 on the Kissimmee Prairie to 1.40 on the Webb WMA study areas. Frequency of juveniles/100 cranes ranged from a low of 14.9 on

Table 3-17. Mean brood size and number of juveniles in the population during August-October road surveys, 1984-1986.

Area	Km driven	N cranes	N juv	$\bar{X}$ brood	Recruitment: Juv/100 adults	Recruitment: Juv/ total
1984						
Webb WMA	295	89	5	1.3	6.0	5.6
Myakka River SP	152	169	14	1.2	9.0	8.3
Kissimmee Prairie	387	398	40	1.2[a]	11.2	10.1
1985						
Webb WMA	294	92	6	1.2	7.0	6.5
Myakka River SP	349	210	16	1.1	8.2	7.6
Kissimmee Prairie	302	334	30	1.2	9.9	9.0
1986						
Webb WMA	249	98	21	1.4	27.2	21.4
Myakka River SP	269	239	36	1.4	17.7	15.1
Kissimmee Prairie	390	526	68	1.3	14.9	12.9

[a] Two sets of chicks not included because sibling status could not be determined.

the Kissimmee Prairie to a high of 27.2 on the Webb WMA (Table 3-17). During the 1986 fall surveys, large areas of the Webb WMA was searched for families on 4 different days. In all 26 adult and 7 fledged-juvenile cranes were observed. This represents a recruitment rate of 26.9 juveniles/100 adults on the management area.

Discussion

Validity of Aerial Survey Estimates

My aerial survey crude density and population estimates probably are underestimates as a result of visibility bias and errors in flight procedures. While it was not possible to determine a correction factor, the results from 1 of the 3 quadrat, and 3 of the 4 fixed-strip helicopter experiments indicate that we were missing nests. Further experiments with helicopters and replications should provide a reasonable correction estimate for overlooked nests.

Even the best observers tend to underestimate numbers (Norton-Griffiths 1975, Caughley et al. 1977). LeResche and Rausch (1974) found that under ideal conditions, experienced observers counted 68% and inexperienced observers counted 43% of the moose (*Alces alces*) present on their study area. They found that the accuracy of the counts was significantly affected by observer's current experience, number of observers, snow and light conditions, habitat and terrain, and time of day.

This study suffered from a lack of consistent personnel throughout the study. In 1985, I used 3 pilots for the Webb WMA and Myakka River SP fixed-wing transect surveys. One pilot flew 6 of the 8 surveys, and the other 2 pilots, 1 survey each. On the Kissimmee Prairie, I had 1 pilot for 5 fixed-wing surveys, and a second pilot for 2 surveys. In 1986, I had the same pilot for all 9 fixed-wing surveys on the Kissimmee Prairie; however, I had 3 different pilots fly 1, 3, and 5 fixed-wing surveys, respectively, on the Webb WMA and Myakka River SP. Prior to my surveys, only 1 of the pilots had experience flying fixed-strip transects. In addition, many were not familiar with the terrain.

While I was an observer on all flights, the second observer varied by season, and to a certain extent between flights. For 1985, another individual served as second observer on all but 3 of the 15 surveys, and for 1986 one individual served as second observer on all but 3 of the 20 flights. The second observer also was at a physical disadvantage in the back seat which may have affected their results as they often became drowsy and on at least 1 occasion was airsick.

The lack of a full-time navigator and a consistent pilot also may have negatively biased both transect repeatability and population estimates by inaccurate calculations of strip width due to banking, and wrong altitudes. Throughout the study, I served as both observer and navigator. The latter job proving to be both demanding and distracting. I believe that my estimates and repeatability could have been improved if there had been a navigator to keep the pilot on course and to monitor the plane height. The added weight of a navigator, however, would necessitate flying at a higher altitude for safety reasons.

Despite their technical difficulties, systematic transect surveys did provide reliable estimates of the relative number of breeding Florida sandhill cranes on each of the 3 potential whooping crane reintroduction sites at a minimum cost of manpower and time. Because the methodology was standardized, it is possible to compare densities of breeding pairs both over time and across the 3 areas (Seber 1982). The systematic transect surveys provide not only density and population estimates but also important information on breeding pair distributions and habitat preferences.

Systematic transect sampling can produce results comparable in precision to both random transect sampling and stratified random sampling. Systematic transect sampling is most precise when there are no periodicities in distribution, and when there are a large number of samples (Yates 1949, Pennycuick et al. 1977). When transect samples are less than 30, as mine were, however, the standard error tends to be biased (Caughley 1977). This bias is due in part to the assumptions of the frequency distributions underlying the estimates (Caughley 1977, Eberhart 1978).

In my case, the ratio estimation method used to calculate the breeding pair population estimates assumes a normal distribution. The low numbers of nests counted in transects, and the high variability between transects for each survey and over the whole season, however, may make the assumption of normality inappropriate. For most of the surveys, the 95% confidence intervals determined from this ratio estimation method included zero or a negative number. Although in theory a statistical correction can be made, presently there are no guidelines for how this correction can be accomplished.

Length of Breeding Season

Florida sandhill cranes in central Florida have a longer breeding season than was previously reported. Earliest and latest estimated laying dates during this study ranged from late December through 20 May, approximately 43 days longer than the 5 January through 10 April laying dates recorded by Walkinshaw (1987) for the Kissimmee Prairie. The total length of the 1986 season on the Webb WMA (128+ days) and Kissimmee Prairie (168 days) is longer than any reported for populations in north Florida (104 days) (Nesbitt in press) or Okefenokee Swamp (110 days) (Bennett and Bennett 1987).

Initial laying dates for cranes in central Florida are 1 and 2 months earlier than those reported for populations in north Florida (1 February) (Nesbitt in press) and Okefenokee Swamp (26 February) (Bennett and Bennett 1987), respectively. The average peak nesting densities for 1984-1986 on the Kissimmee Prairie (4 March) and the Webb WMA (14 March), however, are similar to the 12 March peak for north Florida cranes and the 10-25 March peak reported for Okefenokee Swamp. In contrast, Myakka River State Park has recorded a later than average peak (6 April) for all 3 seasons.

Proximate Factors Influencing Breeding Initiation and Renesting

Breeding seasons are regulated by ultimate and proximate factors. Ultimate factors are those environmental factors that control the efficiency of breeding and have evolved in relation to the needs of the laying female, egg requirements, and optimum survival of the young. Ultimate factors include food supply, competition, nesting conditions, predation pressure, ambient temperature, and the indirect influence of climate through changes in vegetation and the food supply (Immelmann 1971).

Proximate factors provide the timing mechanisms whereby breeding adaptations are achieved. Proximate factors include both endogenous controls and environmental stimuli that predict an oncoming improvement of environmental conditions. At middle and high latitudes, the most important proximate factor is the seasonal change in photoperiod. The increasing daylength after the winter solstice stimulates gonadal development via neurohypothalamic pathways. While male birds can be brought into reproductive condition by light stimulation, female birds are only partially stimulated and need additional proximate factors for egg-laying to commence. These additional factors often are identical to ultimate factors and can include food supply, appropriate behavioral stimuli from the mate, population density, temperature, change in landscape, territorial establishment and acquisition of a nest site (Immelmann 1971, Murton and Westwood 1977).

Initiation of Breeding. Several investigators have pointed out the significance of precipitation and water levels with regards to successful Florida sandhill crane nesting (Bent 1926; Walkinshaw 1949, 1982; Thompson 1970; Bennett and Bennett 1987; Nesbitt in press). Walkinshaw (1987) suggested that initiation of nesting in central Florida was influenced by the amount of rainfall more often than air temperature or the length of day.

Both the multiple regression analyses and simple correlations between nesting densities and environmental variables suggest that wetland habitat conditions are important proximate factors for nest initiation in central Florida. In particular, the lack of water in otherwise suitable nesting wetlands, apparently will cause potential breeders to forego nesting.

Of the 3 water-related variables (water depth, precipitation, and water level dry/rise rate) demonstrating positive significant correlations to densities of breeding pairs, water depth showed the strongest relationship. For a potential nesting or renesting crane, water depth may be a source of environmental information in 2 ways. First, it may indicate the adequacy of both the present and future food supply. Second, water levels also may provide information relative to predation pressure. The prolonged incubation period (approximately 30-32 days), combined with low water levels or a lack of water in wetlands, make a nesting crane and its eggs potentially more vulnerable to predation by bobcat (Lynx rufus), raccoon (Procyon lotor), red fox (Vulpes fulva) and feral hog (Sus scrofa).

In their studies of arctic-nesting greater sandhill cranes, Krapu et al. (1985) suggested that because adult cranes have high survival rates (Johnson 1979), they would be expected to invest less in current reproduction than would a species with a lower expectation of future offspring. In the case of the Florida sandhill crane in central Florida, the long (5 month) breeding season allows for a choice of several breeding strategies. Given suitable habitat conditions a crane can nest, and/or renest if initially unsuccessful and both time and conditions permit. Alternatively, if habitat conditions are not suitable, a potentially reproductive crane can either delay nesting for up to several weeks until habitat conditions improve or forego nesting for the entire season. During this study, the low numbers of breeding pairs detected during flights on all 3 areas during the 1985 drought conditions, as compared to the 1984 and 1986 breeding populations, indicate that a large proportion of the local population may not nest when low-water conditions exist.

Affects of ditching. The high number of ditched wetlands on the 3 study areas may decrease the length of the breeding season, due to a shortened hydroperiod. In a hydrological study of wetlands on the Ringling-MacArthur Reserve on the Myakka River SP study area, CH2M HILL (1988) found that water levels in ditched wetlands averaged 30-61 cm lower than the mean water level of unditched wetlands. They found that during the rainy season, ditched wetlands reach peak water levels 2-4 weeks later than unditched wetlands, and that subsequently water levels dropped much faster in the ditched wetlands. During 1986, they found that the hydroperiod for unaltered wetlands was 313 days (range 289-350 days), and for 5 altered wetlands the average was 173 days (range 137-243 days).

Renesting. Walkinshaw (1987) does not report renesting attempts on the Kissimmee Prairie during his 1967-1987 nesting studies. While the scope of this project did not permit an in-depth study of nesting success and renesting, renesting was recorded on several occasions. Totals observed on all 3 study areas during 1986 included 8 renests on the Kissimmee Prairie, 5 on the Webb WMA, and 1 on Myakka River SP. Of 4 radioed breeding pairs monitored on the Kissimmee Prairie, 2 pairs renested once each, indicating that renesting may be common.

Although the nesting season in north Florida and Okefenokee Swamp begins 1 to 2 months later than cranes in central Florida, and ends at approximately the same time, studies of color-marked Florida sandhill cranes on both of these areas indicate that renesting can be of major significance to net reproductive success. In Okefenokee Swamp, Bennett and Bennett (1987) found that the incidence of renesting was closely correlated with water levels. During a drought they documented a renesting rate of 13.3%, and during high water seasons found renesting rates of 53.3 and 80%. In north Florida, Nesbitt (in press) reported pairs renesting up to 4 times when favorable conditions prevailed. In experiments with clutch removal, he found that 76% of the pairs robbed of first clutches later renested. During the nesting season, an estimated 35% of all nests were renests (S. Nesbitt, pers. commun., 1987).

Comparison of Nesting Densities and Annual Juvenile Recruitment

Breeding pair density estimates. Total breeding pair estimates for all 3 study areas are lower than those reported previously by Walkinshaw (1976). He reported densities of cranes on the Kissimmee Prairie to be 0.78 to 0.87 pairs/km^2, whereas aerial survey crude density estimates for the Kissimmee area for 1985 and 1986 were 0.05 and 0.25 pairs/km^2, respectively. Although my estimates include a 35% downward readjustment for estimated renesting, the differences in estimated densities underscores the importance of year to year variation, as well as differences in the areas searched and the methodology used to estimate densities.

In Okefenokee Swamp, Bennett and Bennett (1987) found that densities averaged 0.7 pairs/km^2. This average, however, is based on breeding pairs in prairie habitat, and does not encompass the entire swamp. In this study, however, I have based my estimates on the total area within the surveyed area. All 3 central Florida survey areas are characterized by heterogenous habitat. That is, wetlands are juxtaposed with upland habitats including pine flatwoods, dry prairie, and improved pastures. Thus, it is misleading to compare my estimates to those for Okefenokee Swamp.

Juvenile recruitment rates. My fall surveys probably underestimate juvenile recruitment because families that stay on territories, especially territories in remote areas, are not as detectable as families found in the fall aggregations. Some family groups also may not roost communally during this time. In particular, the number of juveniles/100 adults on the Webb WMA study area probably was low during the 1984 season, due to limited access to the area.

Despite the low number of nesting attempts recorded on all 3 areas during the 1985 drought, a juvenile recruitment rate of 8.2 and 9.9 juveniles/100 adults on Myakka River SP and Kissimmee Prairie may reflect the importance of individual reproductive performance. That is, cranes that did nest possibly were the more experienced, proven breeders who also are good parents.

With the exception of the high recruitment rates recorded for 1986, the range in juvenile recruitment rates for all 3 areas (annual range from 6.0 to 27.2) is comparable to recruitment in Okefenokee Swamp (annual range from 7.7 to 11.6 for 1985-1987) (Bennett and Bennett 1987) and north Florida (annual range from 8.5 to 13.0 for 1985-1987) (Nesbitt 1988). In contrast, juvenile recruitment rates for my 3 study areas tended to be much lower than those reported previously by Layne (1983) in south-central Florida (range of 18.6 to 56.5 juveniles/100 adults over 7 years). Layne, however, only counted isolated pairs in determining this ratio. His results, therefore, probably are inflated because he did not count large flocks that included unsuccessful breeders, breeders that did not initiate breeding that year, family groups, and subadults.

CHAPTER IV
HOME RANGE OF FLORIDA SANDHILL CRANES ON THE KISSIMMEE PRAIRIE, FLORIDA

Introduction

The Florida sandhill crane (Grus canadensis pratensis) is 1 of 3 sedentary subspecies of sandhill cranes and ranges from the Okefenokee Swamp south to the Florida Everglades. Since 1980, the Florida Game and Fresh Water Fish Commission (FGFWFC) has been evaluating the possibility of establishing a third wild flock of whooping cranes in central Florida (FGFWFC 1981), the heart of the Florida sandhill crane's population (Walkinshaw 1976). If the whooping crane is reintroduced in central Florida, it is possible that their movements and habitat selection will be similar to that of the resident Florida sandhill cranes.

Currently, there are 2 wild, migratory flocks of whooping cranes, the Wood Buffalo National Park (NP) Canada and Aransas National Wildlife Refuge (NWR) flock, and a reintroduced cross-fostered flock that summers in Idaho, Wyoming, and Montana, and winters in New Mexico. Observations of both unmarked and color-marked whooping cranes in the Canada-U.S. flock have provided information on breeding territories and subadult summering areas at Wood Buffalo NP (Kuyt 1978, 1979a, 1979b, 1981; Kuyt and Goossen 1987), and wintering territories and habitat selection by adults and subadults at Aransas NWR (Blankinship 1976, Labuda and Butts 1979, Bishop and Blankinship 1982, Bishop 1984, Hunt 1987, Stehn and Johnson 1987). Movements and habitat selection by radio-tagged families and subadults during both spring and fall migration also have been documented (Howe 1987, Kuyt 1987). In the reintroduced Idaho-New Mexico flock, whooping cranes have adopted movements and habitat preferences similar to their foster parents and sandhill crane cohorts (Drewien and Bizeau 1978, 1981).

Of the 3 nonmigratory sandhill crane subspecies, the Mississippi (G. c. pulla) and Florida sandhill cranes have been studied extensively; however, there has been no new information on the Cuban sandhill crane (G. c. nesiotes) since the early 1950's (Walkinshaw 1981, 1987). The Mississippi sandhill crane subspecies has been recognized only recently (Aldrich 1972) and is found in Jackson County, Mississippi. The population is less than 50 individuals, and is officially listed as endangered by the U.S. Fish and Wildlife Service (38 Federal Register 14678, 4 June 1973). Prior to 1981, information on the Misssissippi sandhill crane was available primarily on the nesting ecology (Valentine 1982). Since that time, multiple releases of radio-tagged captive-reared birds and the capture and color-marking of wild birds have provided information on movements and habitat use of this subspecies (Mitchell and Zwank 1987a,b; Valentine 1987).

During the past decade, Florida sandhill crane populations in north central Florida and Okefenokee Swamp have been studied in detail by color-marking and radio-tagging individuals. Information on these 2 populations has been gathered on nesting ecology (Bennett and Bennett 1987, Nesbitt in press), social behavior (Nesbitt and Wenner 1987, Bennett and Bennett in press), and habitat selection and home range (Bennett in press, Bennett and Bennett 1987, Nesbitt 1988).

The proposed Florida release site for whooping cranes is in the Kissimmee Prairie region in the central part of the state. Information on Florida sandhill cranes on the Kissimmee Prairie and other crane populations in central Florida has been previously limited to the breeding season and estimates of breeding pairs with young (Walkinshaw 1976, 1981, 1982, 1987, in press; Layne 1983). Although home range and habitat selection have been reported in the Okefenokee Swamp and northern Florida, habitat conditions reported in these studies are not representative of the Kissimmee Prairie.

The objectives of this study were to (1) determine the home range size and interpret the variation in home range as it relates to social status and season, (2) determine the habitat requirements of Florida sandhill cranes in central Florida, and (3) evaluate social behavior and activities of breeding pairs throughout the year.

Study Area

I studied a population of Florida sandhill cranes on the Kissimmee Prairie near Kenansville, Osceola County, Florida from July 1985 through January 1987. The area is characterized by poorly drained sandy soils, and a relatively flat terrain with elevations ranging from 14 m to 23 m. Dominant native vegetation types on the Prairie include broad saw-palmetto (*Serenoa repens*) prairie, pine flatwoods characterized by slash pine (*Pinus elliottii*), cypress (*Taxodium* spp.) strands and domes, freshwater marshes, and wet prairies. Cattle ranching and sod farming are the primary land uses on private lands, and much of the dry and wet prairie habitat on these ranches has been converted to improved pasture.

Long-term rainfall for the area averages 131 cm per year and is seasonal (South Florida Water Manage. District, unpubl. data). Between 70-80% of the rainfall occurs from May through October. Florida sandhill crane nesting occurs during the dry season, from January through late May (see Fig. 3-1).

Methods

Determination of Home Ranges

From 15 July through 27 October 1985, intensive baiting of cranes with shelled corn (*Zea mays*) was successfully used on 7 feeding concentration sites north of SR 60 (Fig. 4-1). For all trapping attempts, cranes were drugged at the bait site using corn dosed with 0.43-0.44 g alpha-chloralose per 284 cc of corn (Williams and Phillips 1972, Nesbitt 1976). Additionally, flightless chicks 40-60 days old (hereafter referred to as prefledged) throughout the study area were captured during spring 1985 and 1986.

All captured cranes were weighed, measured, aged by flight feathers (Nesbitt 1987), individually color-marked and fitted with U.S. Fish and Wildlife Service leg bands. Selected cranes were outfitted with leg-mounted radio transmitters (Melvin et al. 1983) weighing approximately 61 g. Transmitters (manufactured by Telemetry Systems Inc., Mequon, Wisconsin) were equipped with a combination of solar panels and rechargeable NiCd batteries.

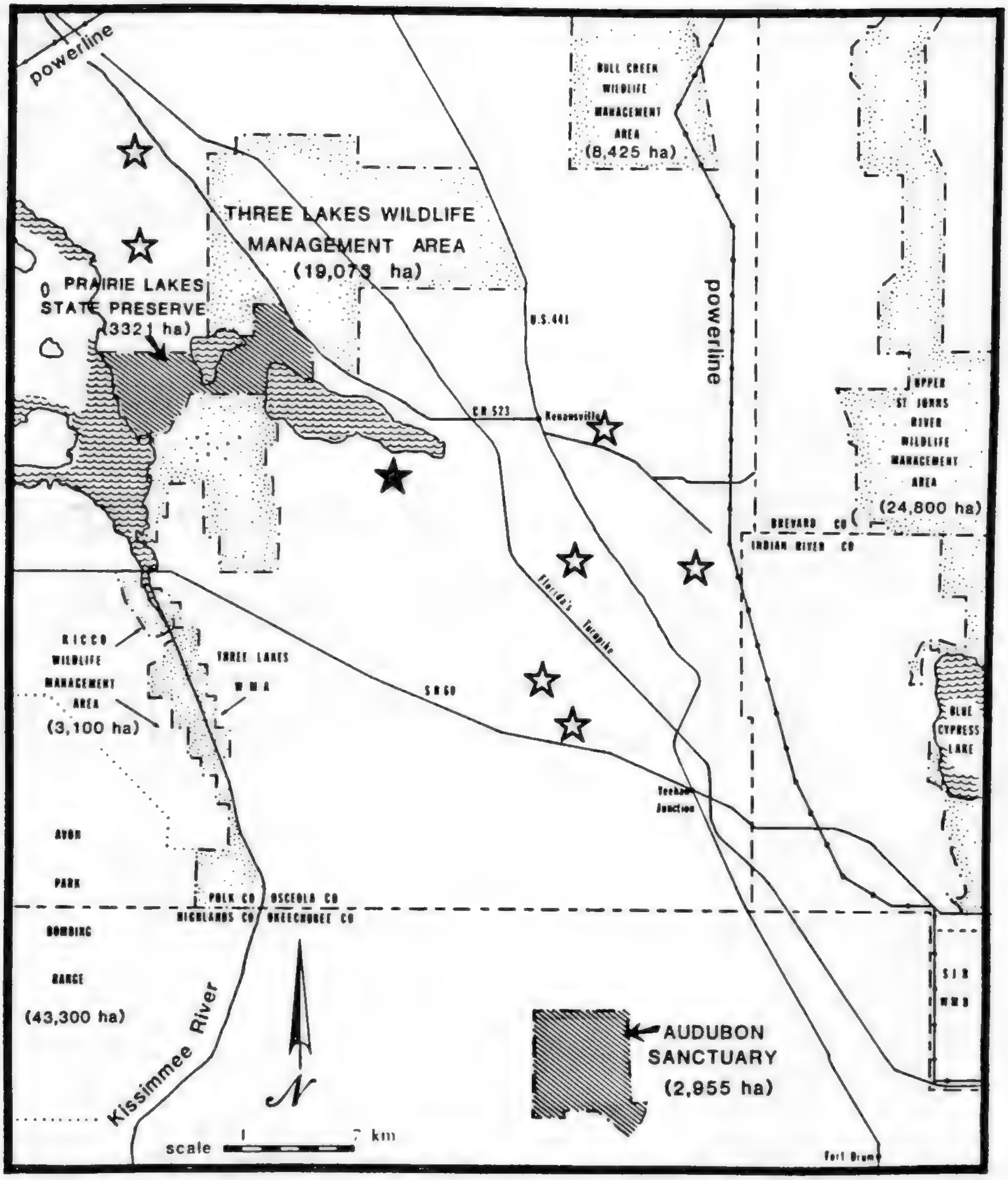

Figure 4-1. Locations of 7 feeding concentration sites (white stars), and 1 bait site (black star) where Florida sandhill cranes were trapped and color-marked, Kissimmee Prairie, Florida, July 1985 - January 1986.

Searches for radio-tagged cranes were conducted primarily by vehicle, and on 5 occasions by aircraft, using portable receiving equipment. A signal was followed until the crane was located visually to precisely determine habitat utilization. When a crane was not visible at close range, such as at nighttime roosts, signal strength and direction was used to approximate its location. Each time a crane was located the following data were recorded: date, time, location, habitat, activity, and presence of other animals in the area. Locations were plotted in the field on 1:4,800 aerial photographs and later converted to Universal Transmercator grid coordinates for analysis.

Whenever possible, radio-tagged cranes were located from the ground at least once a month during 4 time intervals (0700-1100h, 1100-1500h, 1500-1900h, and roost). Roost locations usually were identified in conjunction with the 1500-1900h fix.

Home range size (ha) of the radio-tagged sandhill cranes was determined using 3 methods: (1) harmonic mean (Dixon and Chapman 1980); (2) minimum convex polygon (Mohr 1947); and (3) modified minimum area (Harvey and Barbour 1965). Here, home range is defined as the area occupied by an individual in its normal daily activities of food gathering, mating, and caring for young (Burt 1943).

Of the 3 methods, only the harmonic mean is based on a statistical distribution. The harmonic mean measure of activity is based on the harmonic mean of an areal distribution. This method plots isolines that are correlated with areas of equal activity of an animal within its home range (Dixon and Chapman 1980). In this study, the isolines that encompassed 50% of the radio-locations were considered a "core area", and the 95% isolines the home-range boundary. A three-dimensional representation of home range use was produced using PROC G3D in SAS/GRAPH of the Statistical Analysis System (SAS) (SAS Inst. 1985b).

The minimum convex polygon and the modified minimum area measures are nonstatistical methods, and are not based on areal statistical distribution of activity loci. With the minimum convex polygon, the smallest convex polygon is drawn that contains all the observed locations and the area within this polygon is the estimated home range (Mohr 1947).

The modified minimum area method uses a maximum range-length to determine the outer boundaries of the convex polygon(s). If the distance between 2 outer points is greater than the selected maximum range-length, the 2 points are not connected. In this manner, locations falling farther than the maximum range-length from any other location, such as sallies, are excluded from the total area of the home range polygon(s) (Harvey and Barbour 1965). Following the protocol of Harvey and Barbour (1965), the maximum range-length for this study was defined as 0.25 the greatest distance between 2 fixes over the year.

Previous radio-telemetry studies of crane home ranges and activity ranges during migration (Melvin 1978, Melvin and Temple 1983, Bennett and Bennett 1987, McMillen 1987, Nesbitt 1988) have used either the minimum convex polygon method or the harmonic mean method. These 2 measures, therefore, are presented to make the results comparable with other studies. Discussion of home range size in this paper will focus primarily on the modified minimum area.

An annual home range size (ha) for all radio-tagged chicks or paired adults was determined using all 3 methods. In addition, breeding and nonbreeding seasonal home range was calculated using the modified minimum area method. Breeding season was defined as 1 week prior to nest initiation through the completion of incubation or chick fledging (approximately 65-70 days after hatching). Seasonal home ranges were calculated only for those birds for which I had $\geq$ 12 locations.

Because of the limited observations of radio-tagged subadult and unpaired adult cranes, an annual home range (ha) was calculated using only the minimum convex and modified minimum area methods. During the course of this study, the social status of 2 individual cranes changed from a chick to a subadult, and from a paired adult to unpaired adult, respectively. For these 2 cranes, an annual home range was calculated separately for observations in each social class.

All home range calculations were accomplished using a microcomputer. The TELEM (Coleman and Jones 1986) and McPAAL (Stuwe 1985) programs for analyses of animal locations were used to plot home ranges.

Home range size estimates produced by the 3 methods were compared using Student's *t*-tests. Social class differences in home range size also were compared using Student's *t*-tests. The paired *t*-test was used to compare seasonal changes in home range for breeding pairs and families. Overlap among paired cranes and families was calculated as hectares of shared area and percentage of home range.

Habitat Use

Habitat types were identified from 1:4,800 aerial photographs and ground reconnaissance. Habitats were classified as wooded wetlands (>30% shrub-scrub or cypress cover), herbaceous emergent wetlands, improved pasture, dry prairie (saw-palmetto and wiregrasses (*Aristida* spp.)), croplands and plowed improved pastures, pine flatwoods, oak hammocks, and roads. Croplands included corn stubble, cultivated chufa (*Cyperus esculentus*), and food plots with broadcast corn, wheat and millet. Plowed pastures included those where sod had recently been removed, or those recently plowed for winter cover and forage grasses.

Diurnal and seasonal habitat use was determined from all locations, excluding locations on the nest and at evening roost sites. Three habitat categories were used for these analyses: herbaceous wetlands, improved pastures and other (including pine flatwoods, oak hammocks, croplands, roads, and wooded wetlands). Diurnal habitat use was analyzed by grouping the locations into 3 time periods: 0700-1100h, 1100-1500h, 1500h-Roost and then determining the percentage of locations within each interval. Habitat use also was divided into four, 3-month seasons. These seasons were February-April, May-July, August-October, and November-January.

Diurnal and seasonal habitat data were analyzed for the adult/chick social class, and diurnal habitat was analyzed for the subadult social class using both a weighted (by sample size) and non-weighted analysis of variance with the SAS general linear models procedures (SAS Inst. 1985a). Because there was no difference in the results, only the non-weighted analyses will be presented. Percentage of habitat use was used as the response (dependent) variable, and the bird and time were the predictor (independent) variables.

For all monitored chicks and paired adults, a Chi-square test for goodness-of-fit was used to test whether diurnal habitat use, excluding observations on the nest, occurred in proportion to the available habitat types. Expected habitat values were calculated from habitat types within the annual modified minimum home range that had been digitized from 1:4,800 aerial maps. Categories were lumped when expected values for a habitat type was <5%. When a statistical difference of $\underline{P} < 0.05$ in usage versus available was detected, Bonferroni 95% confidence intervals were used to determine which vegetation types were preferred or avoided (Neu et al. 1974, Byers et al. 1984).

Social Behavior

Social behavior was determined from associations observed both at daytime locations (excluding locations at the nest) and at nighttime roosts. For families and breeding pairs without chicks, the proportion of time spent alone (with or without mate or chicks) and time spent with non-related individuals was determined for the four, 3-month seasons. A weighted (by sample size) and nonweighted analysis of variance with the SAS general linear models procedures (SAS Inst. 1985a) was used to test differences in the proportions of social behavior by season. Because there was no difference in the results, only the non-weighted analyses will be presented.

Results

A total of 134 Florida sandhill cranes were captured and color-marked during the study. Of this total, 107 were trapped at 7 feeding concentration sites in 1985, including 5 fledged 1985 chicks. Two cranes were trapped at a bait site in January 1986. An additional 6 prefledged 1985 chicks and 18 prefledged 1986 chicks were captured and color-marked in the vicinity of their nests. All captured birds were Florida sandhill crane residents. Eight cranes were radio-tagged: 5 adult breeders, 1 subadult, and 2, 1986 chicks. Cranes were monitored for 7.5-15 months. It was not possible to monitor 1 of the adult breeders due to the inaccessibility of its territory.

Variations in Home Range Size and Overlap

Of the 3 methods used to calculate annual home range, the modified-minimum area resulted in the smallest home range estimate for all cranes (Figs. 4-2, 4-3). The mean annual home range for 2 chicks and 4 adult-breeders computed by the modified-minimum area (MMA) was 1.83 $\pm$ 1.03 km^2 (SD) and differed significantly ($P < 0.01$) from both the minimum convex method (6.57 $\pm$ 2.99 km^2) and the harmonic mean method (9.91 $\pm$ 4.03 km^2) (Table 4-1). There was no significant difference ($P < 0.13$) between the mean annual home range calculated by the minimum convex method and the harmonic mean method. The large differences in the home range sizes calculated by each of the 3 methods illustrates the importance of methodology with regards to interpretation of home range size (see Discussion).

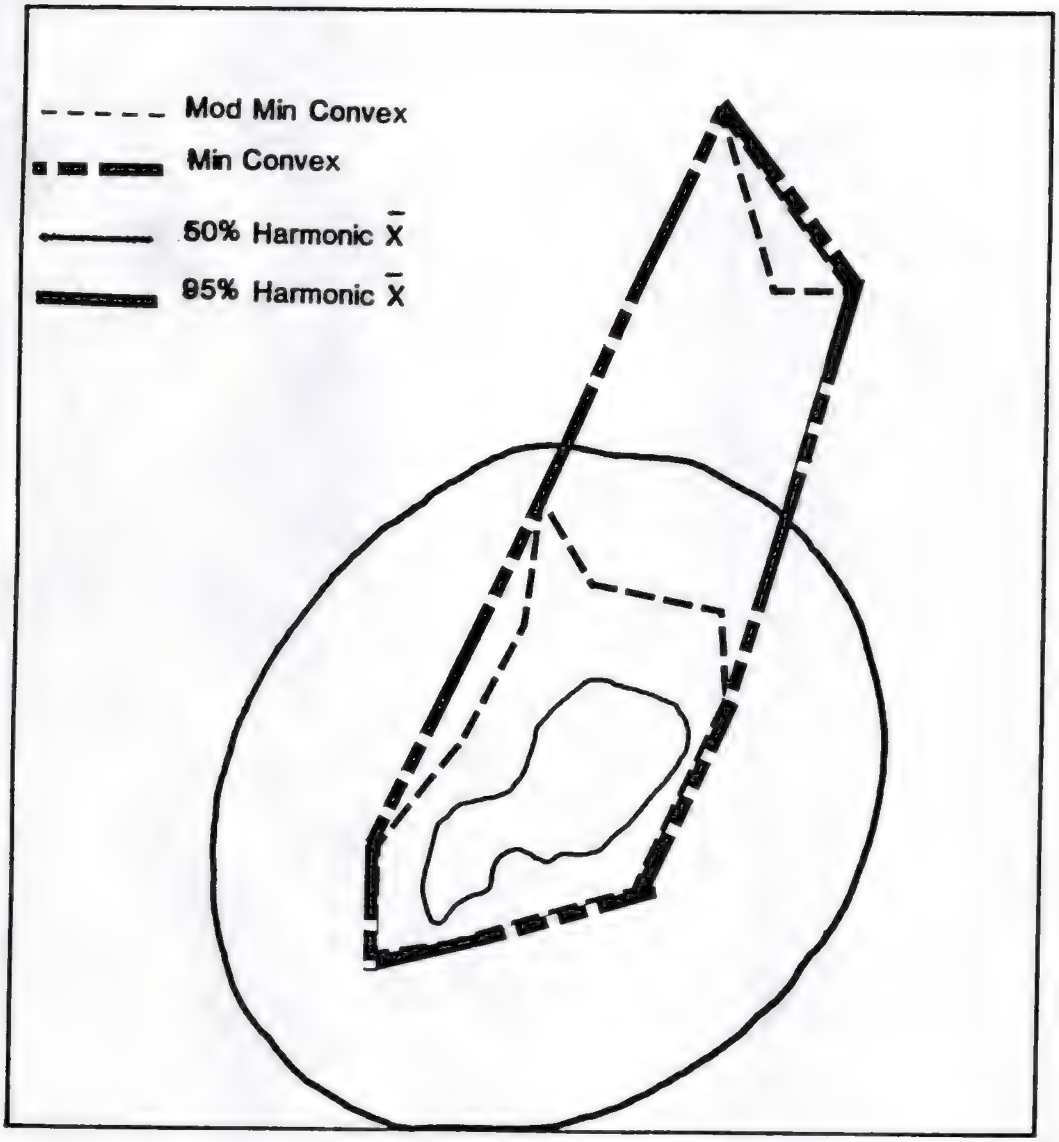

Figure 4-2. Annual home range of AM1 as calculated by 3 different methods: modified minimum convex (291 ha); minimum convex (581 ha); and 50% (92 ha) and 95% (1,133 ha) harmonic mean.

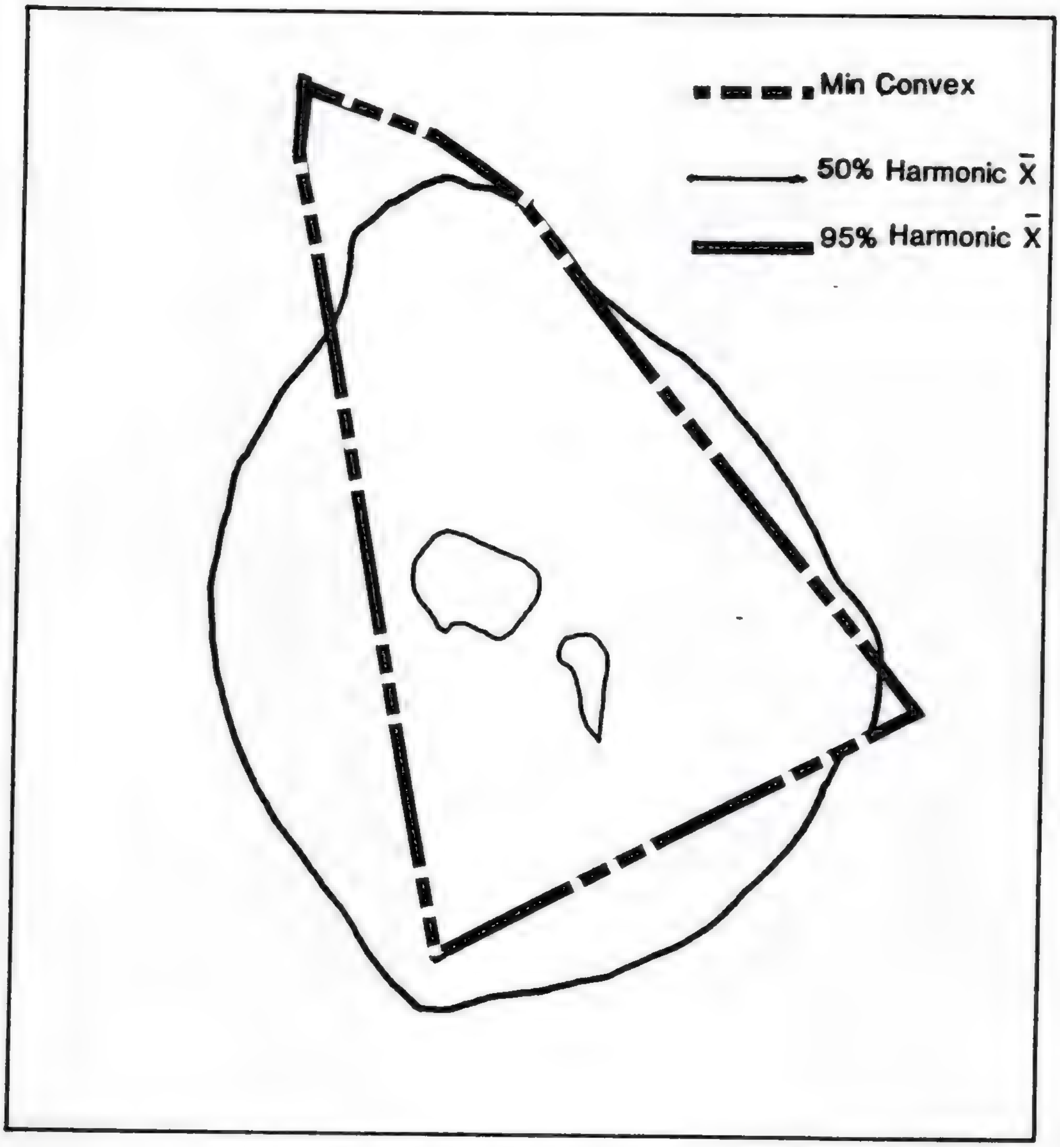

Figure 4-3. Annual home range of AF4 as calculated by 2 methods: minimum convex (1,139 ha), and 50% (51 ha) and 95% (1,595 ha) harmonic mean.

Table 4-1. Annual home range size (ha) for Florida sandhill crane paired adults and chicks using 3 methods, October 1985-January 1987.

Individual	N	Mod minimum convex	Minimum convex	50% Harmonic Mean	95% Harmonic Mean
AM1[a]	111	291	581	92	1,133
AF1	93	275	704	112	579
AF4	103	233	1,139	51	1,595
AM3	55	35	287	14	669
CU1	73	173	797	38	1,262
CU3	71	91	433	34	617
$\bar{x} \pm$ SD		183 ± 103	657 ± 299	57 ± 37	976 ± 417

[a] Letters denote age class (A=adult, C=chick) and sex (M=male, F=female, U=unknown), numeral denotes individual.

Florida sandhill cranes did not use all portions of their home ranges with equal frequency. Activities tended to be concentrated in and around herbaceous emergent wetlands that included the nest site and/or roosting and loafing sites (Fig. 4-4). Core areas (50% isolines) determined from the harmonic mean varied considerably in size among the 6 paired adults and chicks. Values ranged from 14 to 112 ha ($\bar{x}$ = 57 $\pm$ 38 ha), and represented, on average, only 6.8% of the 95% harmonic mean home range (Table 4-1).

All 4 radio-tagged adults nested during spring 1986. Of the 4 adults, 2 renested a second time unsuccessfully (Table 4-2). Home range size differed significantly (paired t-test, $P < 0.01$) between the breeding season ($\bar{x}$ = 0.53 km^2 $\pm$ 0.58 km^2) and nonbreeding seasons, ($\bar{x}$ = 1.66 $\pm$ 0.91 km^2), with the breeding season averaging 71% smaller than the nonbreeding season (Table 4-3).

Three of the 4 monitored pairs hatched 1-2 chicks, and 2 of those pairs, AM3 and AF3 successfully fledged 1 chick. In the case of AM3, 1 month after 2 chicks hatched his color-marked mate separated from him, and re-paired with an unmarked crane. The female remained with her new mate and the surviving radio-tagged chick (CU1) on the terrritory. Seven months later when the chick became independent, AM3 returned to the territory and re-paired with his former mate. Annual home range of AM3 while paired overlapped spatially 77% (27 ha) with the annual home range of his chick's (CU1), although CU1's annual home range was substantially larger (173 ha vs. 35 ha) (Fig. 4-5).

Overlap also was observed between the radioed members of 3 families captured within a 3.2 km^2 area (Fig. 4-5). Total overlap ranged from 7.6 to 27 ha ($\bar{x}$ = 13.41 $\pm$ 4.21 ha), representing 4-22% of

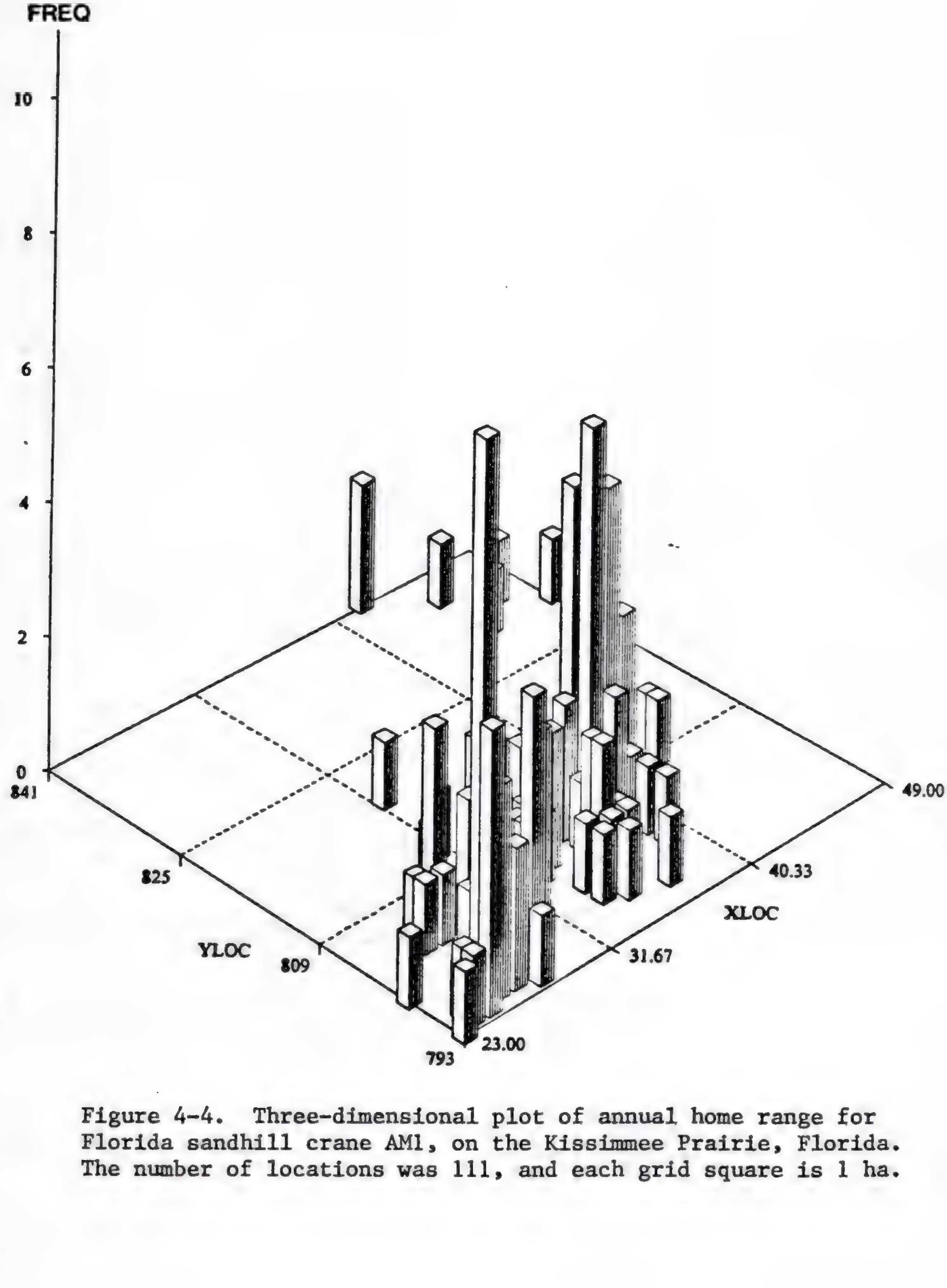

Figure 4-4. Three-dimensional plot of annual home range for Florida sandhill crane AM1, on the Kissimmee Prairie, Florida. The number of locations was 111, and each grid square is 1 ha.

Table 4-2. Summary of breeding attempts by radio-tagged Florida sandhill cranes on Kissimmee Prairie, Spring 1986.

Animal	First nest initiation	Outcome	Second nest initiation	Outcome	Chicks Fledged
AM3[a]	4 February	2 chicks (9-10 March)	--	--	1[b]
AF1	12-16 February	2 infertile (13-20 March)	4-17 April	Abandoned/or destroyed (11-15 May)	0
AM1	15 February	1 chick,1 infertile 18 March	12-17 April	Abandoned/or destroyed (11-15 May)	0
AF4	7 March	2 chicks (7-8 April)	--	--	1

[a] Male separated from mate 1 month after chicks hatched. Color-banded female repaired with unmarked crane for 7 months, after which male returned and re-paired.
[b] Chick CU1 radio-tagged, May 1986.

Table 4-3. Seasonal home range size (ha) of Florida sandhill crane paired adults and chicks, Kissimmee Prairie, Florida, October 1985-January 1987.

Individual	Breeding season home range			Nonbreeding season home range		
	Mod. minimum area	N	Tracking days	Mod. minimum area	N	Tracking days
AM1[a]	152	28	95	255	83	262
AF1	56	12	79	269	81	332
AF4	29	26	107	176	77	338
AM3	13	19	70	34	36	167
CU1	16	15	73	173	58	181
CU3	-	7	18	91	64	207
$\bar{x} \pm$ SD	53 ± 58			166 ± 91		

[a] Letters denote age class (A=adult, C=chick) and sex (M=male, F=female, U=unknown), numeral denotes individual.

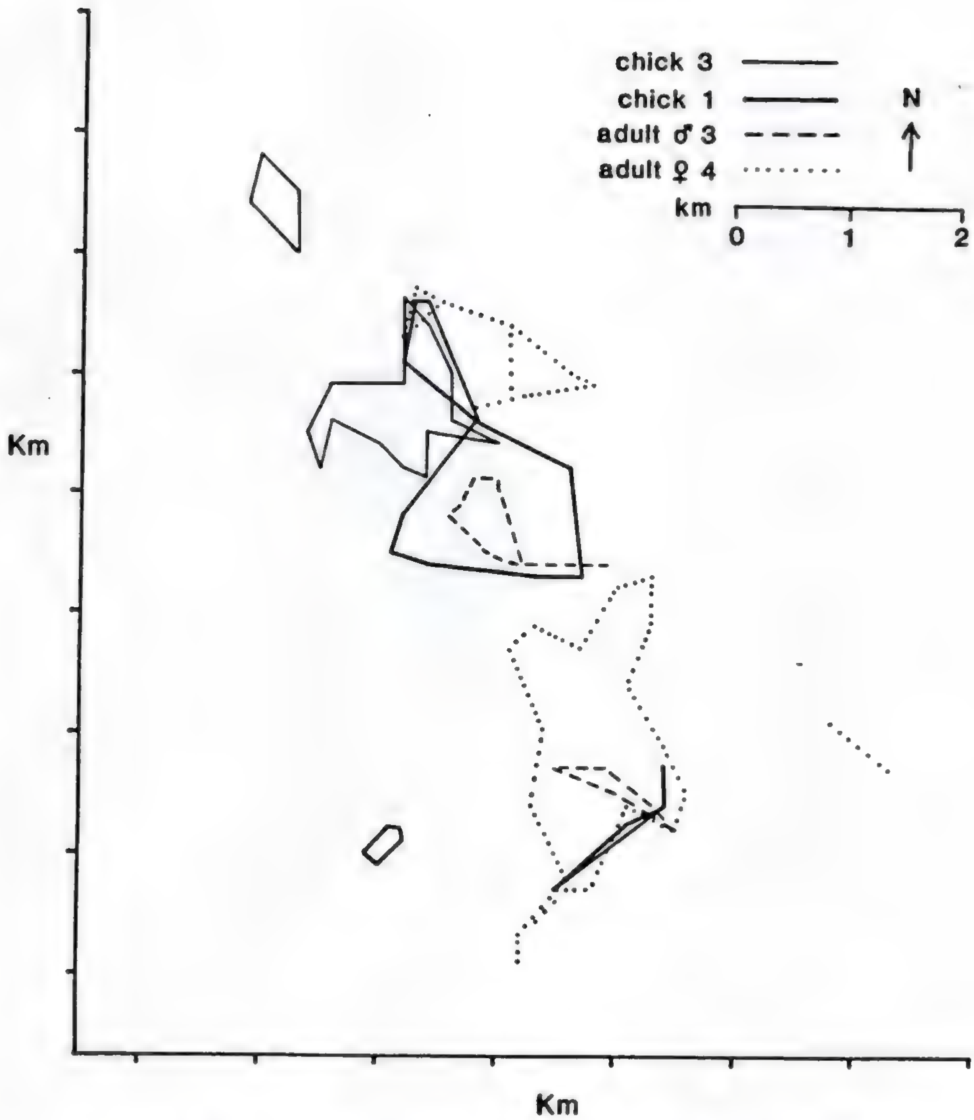

Figure 4-5. Annual home range (modified minimum convex method) of 4 radio-tagged Florida sandhill cranes on the Kissimmee Prairie, Florida, October 1985 - January 1987. Numerals denote individuals.

the annual home range. Home range overlap between all 3 families occurred at the end of the dry season from late May to mid-June 1986, and centered around a wetland roost site that still contained water. Overlap in the annual home range also was observed on 9 occasions at the southern end of the study area, and primarily centered around a recently seeded pasture and a cultivated chufa field.

The 3 radio-tagged cranes exhibiting subadult behavior (hereafter referred to as subadults) during this study were monitored for 2, 7, and 13.5 months. Subadult home ranges increased with the time monitored, and ranged from 131 to 3,853 ha and from 1,352 to 28,798 ha using the modified minimum convex and minimum convex methods respectively (Table 4-4, Fig. 4-6). An adult male-breeder (AM3) that separated temporarily from mate for 7 months, expanded his home range from 34 to 1,319 ha, including most of his paired-adult home range.

Long distance movements between fixes were observed for subadults, but not for paired adults or chicks. Whereas the maximum distance recorded between locations for a chick or paired adult ranged from 2.91 to 4.78 km (N = 6), for subadults it ranged from 7.2 to 31 km (N = 3). For the 2 subadults monitored 7 and 13.5 months, a long distance move between locations was usually followed by temporary (1-4 months) residence in the area.

Nest Site Selection

Three of the 4 pairs monitored selected the largest herbaceous emergent wetlands in their home range: 23.6 ha (AM1), 35.9 ha (AM3) and 51.1 ha (AF3). Crane AF1 nested and renested in a 1.1-ha herbaceous emergent marsh. AM1 also renested in the same 23.6-ha wetland as his

Table 4-4. Annual home range size (ha) for unpaired adult and subadult Florida sandhill cranes, Kissimmee Prairie, Florida, October 1985-January 1987.

Individual	N	Mod minimum convex	Minimum convex	Tracking days
SM1	38	3,853	28,798	412
AM3	50	1,319	6,689	218
CU1	16	131	1,352	58
$\bar{x} \pm$ SD		1,768 ± 1,901	12,280 ± 14,552	

[a] Letters denote age class (A=adult, S=subadult, C=chick) and sex (M=male, F=female, U=unknown), numeral denotes individual.

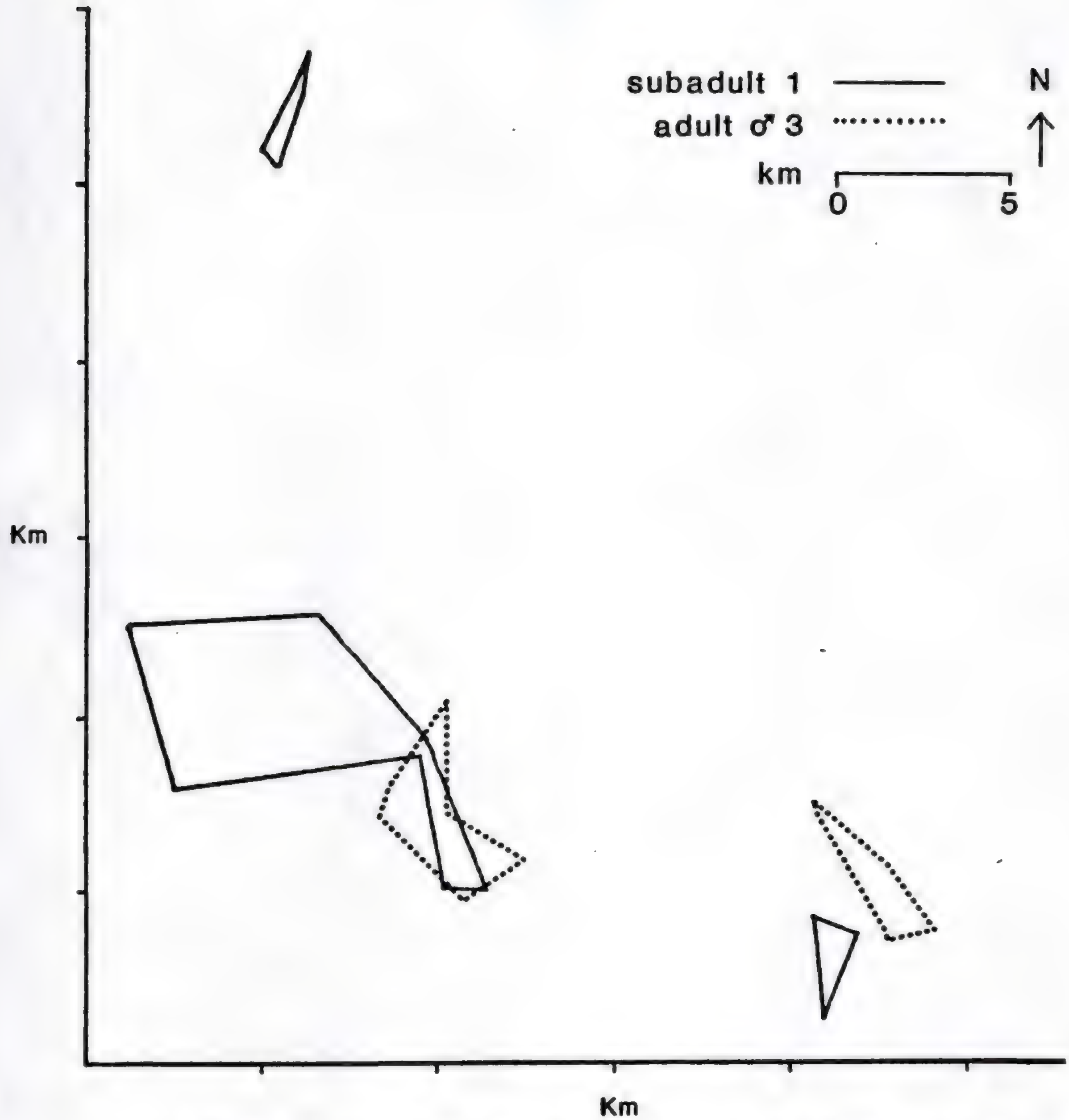

Figure 4-6. Annual home range (modified minimum convex method) of 1 subadult male (SM1) and 1 unpaired adult male (AM3) radio-tagged Florida sandhill crane on the Kissimmee Prairie, Florida, October 1985 - November 1986.

previous attempt. Average water depth within 1 m of the nest for the 4 first nesting attempts was 29.8 $\pm$ 2.63 cm (SD). Water measurements taken shortly after abandonment/or destruction of the 2 renests were 2 cm and 10 cm, respectively.

Nest wetlands had >50% emergent vegetation, and in 75% of the wetlands, the dominant vegetation was maidencane (Panicum hemitomon). Surrounding habitat for the 4 nests was primarily improved pasture, but 2 of the wetlands had pine flatwoods bordering some portions. Average distance from the nest to upland habitat was 31 $\pm$ 18 m (SD) (N = 6).

Nesting by additional pairs in the same wetland was recorded in 3 of the 4 pairs radio-tagged. Simultaneous nesting in the same wetland by 1 other pair at distances of 300 m and 445 m was recorded for AM1 and AF3, respectively. Visual barriers were not present in the case of AM1. The 35.9-ha wetland that AM3 nested in recorded the greatest number of pairs. Subsequent to the hatching of AM3's nest, 3 pairs nested in other "indentations" of the same wetland, and a fourth pair nested in a small adjacent wetland. Distance from AM3's nest to the 4 nests ranged from 205 to 861 m.

Diurnal and Seasonal Habitat Use

A total of 413 daytime locations for adults and chicks, and 88 daytime locations for subadults were recorded in the 8 habitat types. Of all daytime fixes, 3.3% of the adult/chick, and 6.8% of the subadult locations were nonvisual locations based on signal strength and direction. For both the adult/chick and subadult social classes, 93-94% of the daytime locations were in 3 habitat types: cropland and plowed pasture, improved pasture, and herbaceous emergent wetlands (Table 4-5, Figs. 4-7a,b).

Cranes tended to use edge interfaces both on uplands and wetlands. For all cranes, 33% of the observations in upland habitats (improved pasture, cropland, oak hammock, pine flatwoods, and roads) were within 20 m of a different habitat. Sixty-five percent of all herbaceous and wooded wetland observations were within 20 m of another habitat.

For both social classes, improved pasture was the most frequently used daytime habitat, followed by herbaceous emergent wetlands. Morning (0700-1100h) and late afternoon (1500h-roost) hours were spent primarily in improved pastures or croplands. Midday habitat use (1100-1500h) for both groups was characterized by an increased use of wetlands (Figs. 4-7a,b). Time of day effects for habitat use of herbaceous emergent wetlands and improved pasture were only marginally significant ($\underline{P} < 0.08$ and $\underline{P} < 0.09$) for adults and chicks, and not significant ($\underline{P} < 0.30$ and $\underline{P} < 0.43$) for subadults.

There was no significant difference in habitat use by adults and chicks among seasons. The effect of season was only marginally significant for herbaceous emergent wetlands ($\underline{P} < 0.09$) and not significant for improved pastures ($\underline{P} < 0.54$). Among the 4 seasons, herbaceous emergent wetlands were used most often, 43% of all observations, during February-April (Fig. 4-8). This period coincides with nesting and rearing of prefledged chicks. Highest use of improved pastures occurred during May-July (65.9%), while use of herbaceous wetlands dropped from 43% to 31%.

Although the effect of season on use of the "other" habitat category (pine flatwoods, oak hammocks, croplands, roads, wooded

Table 4-5. Percent of diurnal locations, and available habitat within the annual home range (modified minimum convex method) for 4 paired adults and 2 chicks on the Kissimmee Prairie, Florida, October 1985-January 1987.

	Individual					
Habitat	AM1[a] N=89	AF1 N=74	AF4 N=83	CU3 N=64	CU1 N=60	AM3 N=43
Wooded wetland						
% Used	1	1	0	0	2	0
% Available	1	< 1	6	1	6	2
Herbaceous Wetland						
% Used	30	15	31	45	22	47
% Available	11	8	11	27	19	27
Improved Pasture						
% Used	58	78	53	39	75	49
% Available	79	88	60	58	50	59
Dry Prairie						
% Used	0	0	0	0	0	0
% Available	6	0	5	9	7	1
Croplands						
% Used	0	0	11	16	2	2
% Available	0	0	8	2	2	< 1
Pine Flatwoods						
% Used	0	0	5	0	0	2
% Available	0	1	10	2	16	10
Oak Hammock						
% Used	8	4	0	0	0	0
% Available	2	< 1	0	0	0	0
Roads						
% Used	2	1	0	0	0	0
% Available	2	2	1	1	0	< 1

[a] Letters denote age class (A=adult, C=chick) and sex (M=male, F=female, U=unknown), numeral denotes individual.

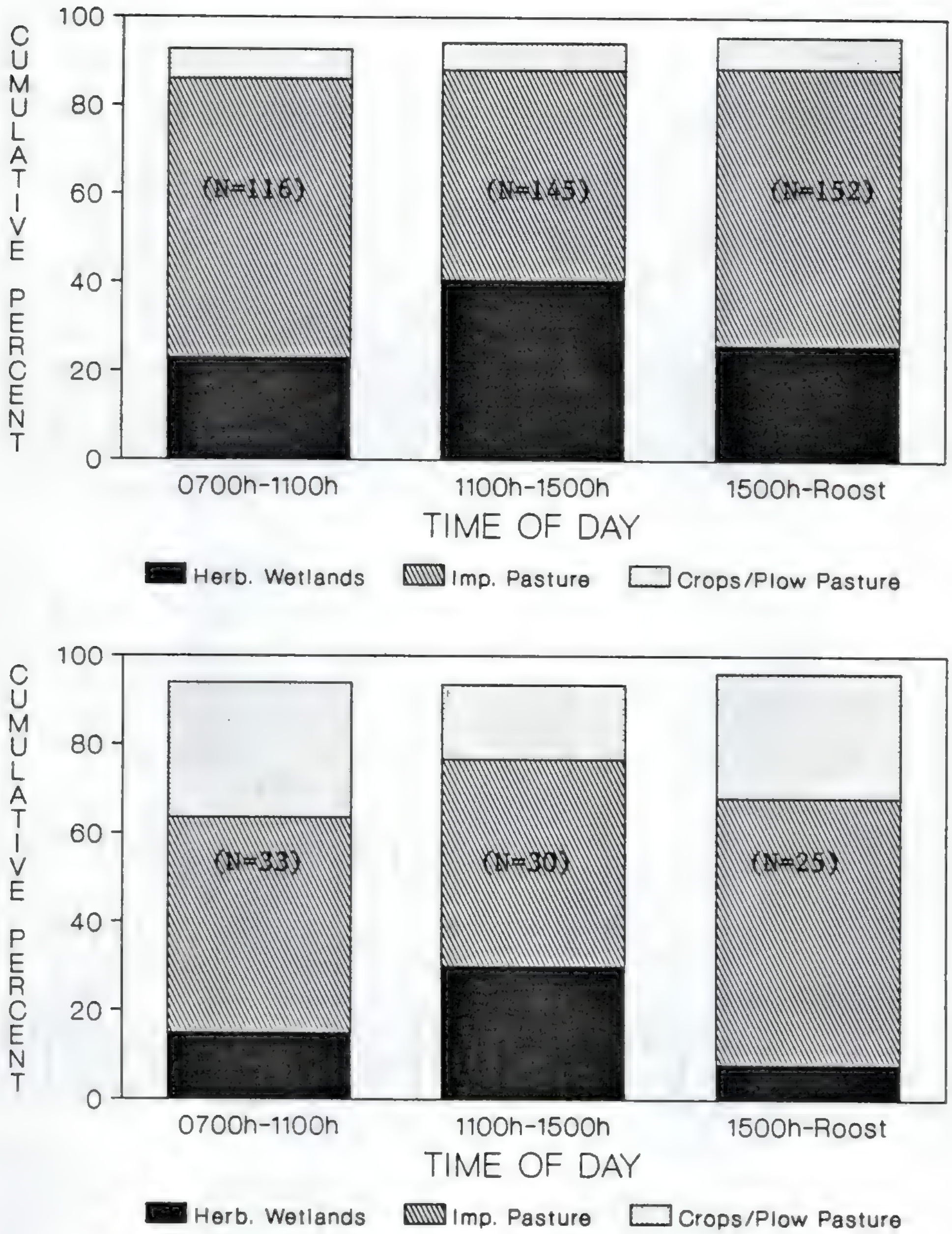

Figure 4-7. Diurnal habitat use by time of day for: (a) 4 paired adults and 2 chicks; (b) 2 subadults and 1 unpaired adult. Locations on the nest are not included.

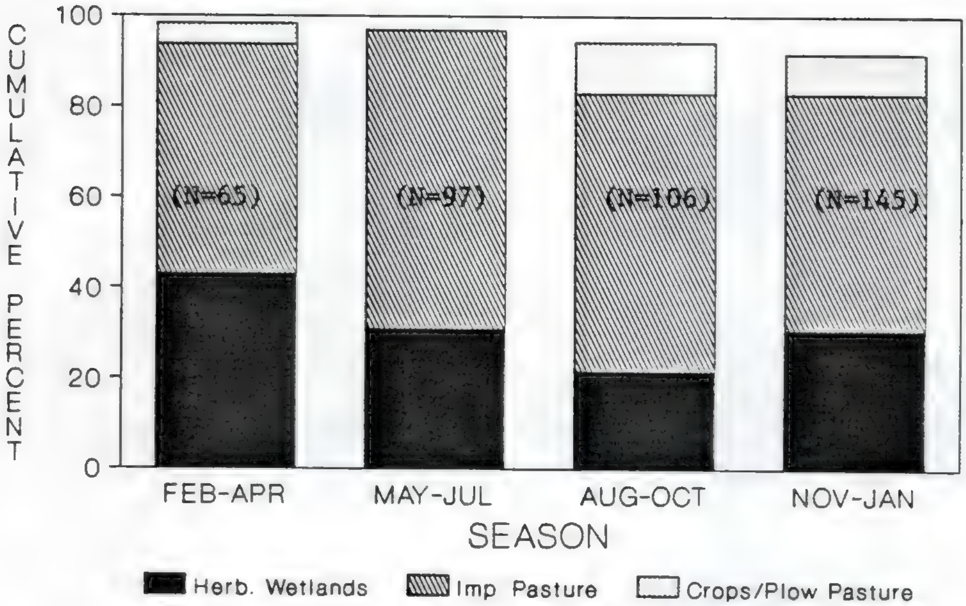

Figure 4-8. Seasonal diurnal habitat use for 4 paired adults and 2 chicks, October-January 1987 (N=413). Locations on the nest are not included.

wetlands) was not statistically significant ($P < 0.11$), this may be due to the pooling effect. For example, oak hammocks occurred on only 2 of the home ranges (AM1 and AF1), and their usage occurred only during August-October and November-January. In 3 of the 6 paired-adult and chick home ranges, some improved pastures or dry prairie were harvested for sod or disced for cover crops during August-October. Croplands and plowed pastures were used most often during these months (11.3%). During the winter (November-January) season, croplands (primarily seeded food plots) accounted for 8.9% of the habitat use.

Habitat Selection

To assess habitat preference by paired adults and chicks, I compared the observed use of habitat types by each crane for all daytime observations (excluding on the nest), with the availability of habitats within its annual modified minimum home range (Table 4-5). When habitats within the home range were delineated for chi-square analyses, for 4 of the 6 cranes, 3 categories of habitat were available: (a) herbaceous emergent wetlands; (b) improved pastures; and (c) "other" including dry prairie, oak hammock, wooded wetlands, and pine flatwoods. Although large cypress sloughs and tracts of pine flatwoods occurred in the general vicinity of 5 of 6 radio-tagged adults and chicks, these areas were avoided, and made up only a small part of the home range using the modified minimum method.

Chi-square analyses of diurnal radio locations indicated that the 4 paired adults and 2 chicks used habitats disproportionately ($P < 0.05$) to their respective availability within their home range (Table 4-6). Herbaceous emergent wetlands were preferred by 4 of the 6

Table 4-6. Use of cover types by 4 paired adults and 2 chicks on the Kissimmee Prairie during October 1985 - January 1987.

Cover type	% Available[a]	% Locations	Number of individuals using cover types		
			Preferred[b]	No Preference	Avoided[c]
Herbaceous Wetland	11 - 27	22 - 47	4	1	0
Improved Pasture	50 - 88	39 - 78	1	3	2
Pine Flatwoods	10 - 16	0 - 5	0	1	1
Croplands	8	11	0	1	0
Other[d]	10 - 16	0 - 22	0	3	3

[a] Calculated as proportion of number of locations to available habitat within annual modified minimum home range.
[b] Use greater than expected ($\underline{P} < 0.05$)
[c] Use less than expected ($\underline{P} < 0.05$)
[d] Depending on the bird, may include all habitats except improved pastures.

cranes, and avoided by none. Improved pasture was preferred by 1 crane and avoided by 2. Three of the 6 cranes avoided the "other" habitats, primarily dry prairie, wooded wetlands, and pine flatwoods. Pine flatwoods occurred in sufficient quantities for analyses in only 2 of the home ranges, and was avoided by 1 (CU1) crane.

Nocturnal Habitat Use

Herbaceous emergent marshes were used most often for night roosting by paired adults and chicks, with 89% (63/71) of the observations occurring in this habitat type. Cranes tended to roost in open water areas of the wetland or where vegetation was minimal and short. Roosting in shallow herbaceous natural and ditched sloughs was observed on 1 occasion each for 4 of the 6 cranes, and accounted for 6% of all observations.

Although the nest pond was used for nocturnal roosting by 5 of the 6 cranes, fidelity to this wetland varied. For 3 cranes (AM3, AF3, CU1), the nest pond was used in 64-100% of all nocturnal roost observations. For the other 3 cranes, the nest pond was used in 0-24% of all nocturnal roost observations.

Social Behavior

Flocking with non-related cranes was observed in the 3 radio-tagged families and 2 adult pairs on roosting, loafing, and feeding areas. Flocking occurred throughout the year and was stimulated by drought, natural and artificially-induced food concentrations, and an increased gregariousness. The tendency to flock appeared to be related to both individualistic behavior and proximity to flock sites.

For the 3 radio-tagged families, the effect of season on sociality was marginally significant (P < 0.03). For these 3 families, their home ranges included food plots and improved pastures that were used by mixed flocks (subadults and adults) throughout the year. Flocking was observed most often from November through January, when 24-54% of the sightings were in flocks (Fig. 4-9). This 3-month period coincided with the presence of 100-200 migrant greater sandhill cranes in the immediate area. Both migrant greater sandhill cranes and resident Florida sandhill cranes fed on seeded food plots intended to attract bobwhite quail (Colinus virginianus floridanus) and mourning doves (Zenaidura macroura). On 1 ranch 3 food plots, seeded 2-3 times a week, attracted as many as 120+ cranes at 1 time. Similarly, an improved pasture where sod was removed attracted flocks of up to 64, including 2 of the 3 monitored families at 1 time.

Throughout the other 3 seasons, flocking by the 3 families was observed in lesser amounts, with only 0-14% of all observations including other cranes (Fig. 9a). The lowest proportions of flocking occurred during the February-April period (0-% and 12%), a period when chicks are either becoming independent, or have recently hatched. In 2 of the 3 monitored families, flock sightings from May through July all occurred at the end of the dry season in late May through mid-June 1986.

Social interactions during May-July were associated with feeding in proximity to and roosting in the only suitable roost site containing water. Anywhere from 17 to 100 resident cranes, including prefledged chicks, roosted in a large (34.4 ha) wetland during this 1 month period. A similar roost site was recorded during this period on the

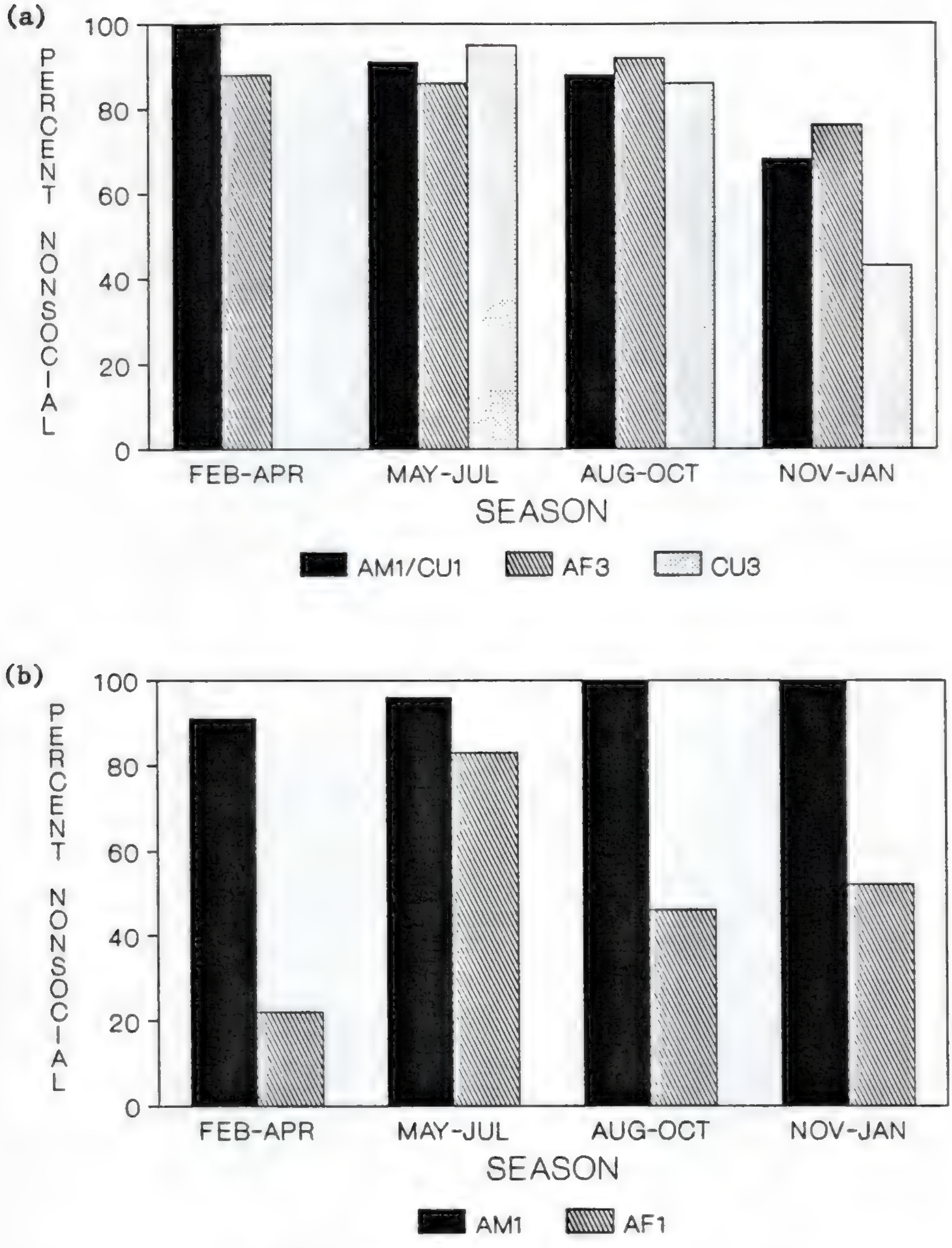

Figure 4-9. Nonsocial Florida sandhill crane behavior (observations without nonrelated cranes) by season for: (a) 3 families, and (b) 2 breeding pairs.

northwest corner of the Kissimmee Prairie study area. There roost flocks numbering over 120 cranes, and including up to 7 families were observed at a 3-ha stock pond.

Although the 3 radio-tracked families did not exhibit an increase in flocking during August-October, recruitment surveys conducted throughout the Kissimmee Prairie during August and September 1987 indicated that a high proportion of flocks contained families. Of 53 families counted, 60% (32) were in flocks of >5 cranes. Flocks with families were observed primarily at roost sites, bull feeders, and in plowed fields.

For the 2 radio-tagged breeding pairs without chicks, the effect of season on sociality was not significant ($\underline{P} < 0.41$) This was a result of the large variation in their flocking behavior. Crane AF1 was observed most often in flocks from February through April (78%, N = 9), and least often from May through July (17%, N = 18) (Fig. 9b). Similar to the 3 families, the home range of AF1 overlapped with an area where mixed flocks occurred throughout the year. Flocks were observed in and around a bull feeder, improved pasture, plowed pastures, and a 3-ha stock pond that served as a year-round roost site.

In contrast, crane AM1 and its mate were observed interacting with other cranes only 3 times over a year's time (N = 104) (Fig. 9b), including 2 agonistic encounters. At the same time, there were few occasions throughout the year when a mixed flock or subadult flock was observed in the area.

Subadults were the most social of the monitored cranes. The 3 radio-tagged subadults were observed in flocks of >2 cranes 81% (N = 94) of the time. Of the flocks observed, 81% (N = 76) were >5 cranes. During November-February, subadults fed and roosted with migrants in flocks numbering up to 400 cranes.

Discussion

Home Range Size

Home range size will vary depending on the sampling design, and the method chosen for analysis (Laundre and Keller 1984). For this study, annual home range is probably underestimated for cranes with <1 year of data, because the seasonality of home range movement was not adequately detected. For example, when the study ended, chick CU3 was approaching independence from its parents and its home range was expanding. For crane AM3, data on its home range as a paired adult was limited from mid-October 1985 through mid-April 1986, and mid-November 1986 through mid-January 1987. A portion of this period coincides with the breeding season, a time when movements tend to be confined to areas on and near the nest pond.

The 3 methods used for analyses demonstrate the large differences in the calculated home range size. For this study, the modified minimum convex method consistently estimated the smallest home range size, whereas, with the exception of 1 crane, the harmonic mean estimated the largest home range size. The differences in areas between the 2 methods ranged from 53% to 95%.

All 3 methods used to determine home range are influenced by both sample size and outliers. For the minimum convex and modified minimum convex methods, the estimated home range usually increases with the sample size. Because only peripheral locations are analyzed in the minimum convex method, outlying points can greatly inflate the home range estimate. For the modified minimum method, the inclusion of peripheral locations will depend on the maximum range-length selected to define the polygon(s). Ideally, a maximum range-length will minimize unused areas within the polygons, while at the same time treating minimal use areas that are great distances from high use areas as single points only.

In contrast to the minimum convex and modified minimum convex methods, estimated home range size using the harmonic mean method tends to decrease with larger sample sizes because outliers tend to have less of an influence than with small sample sizes. Outliers, however, do tend to have more of an influence on large percentage contours (e.g. 95%) than on smaller percentage contours (e.g. 75%). In addition to the effect of outliers and sample size, the home range estimate provided using the harmonic mean is influenced by grid size and scale (Samuel et. al. 1985).

Of the 3 methods used, the estimates of home range area calculated by the modified minimum convex included the least amount of unused habitat. Given the relatively long distances that cranes will fly to forage or roost, the home range areas defined by the modified minimum convex using a maximum range length are intuitively appealing because different use areas that are long distances apart are calculated as separate separate polygons. At the same time, one-time use areas that are great distances from high use areas tend to be calculated as single points only, and have little influence the total home range size area.

Ecological and Behavioral Determinants of Home Range

While home range size offers the possiblity of inter- and intra-specific comparisons, by itself it does not answer how, why, and when an animal uses the area. Ecologists have demonstrated that a correlation exists between the size of the home range and the body size and diet in birds (Armstrong 1965, Schoener 1968, Mace et al. 1983). This concept also has been expanded to include the relationship between body size and productivity of the habitat. That is, the relative density of food items, their pattern of dispersion, and their energy content may influence the relationship between home range size and body size (Harestad and Bunnell 1979, Mace et al. 1983).

The omnivorous diet of cranes allows exploitation of some habitats on a year-round basis. On the improved pastures and croplands on the Kissimmee Prairie, cranes were observed feeding on beetle larvae (Scarabaeidae), mole crickets (*Scapteriscus didactylus*), grasshoppers, (Orthoptera) and chufa tubers. Although it has not been documented in Florida, it is likely that in these same habitats Florida sandhill cranes eat foods similar to what migratory greater and lesser sandhill cranes feed on in native grasslands on the Platte River, Nebraska. These foods included a high (77-99%) intake of invertebrates including earthworms (Oligochaeta), various beetles (Carabidae, Staphylinidae, Scarabaeidae, Elateridae), cutworms (Noctuidae), and snails (Gastropoda) (Reinecke and Krapu 1986).

In the herbaceous emergent wetlands on the Kissimmee Prairie, cranes were observed feeding on various grass (Poaceae) and sedge (Cyperaceae) seeds, and on frogs. Stomach contents of Florida sandhill cranes in north Florida indicate that cranes also feed on dragonflies

(Anisoptera), damselflies (Zygoptera), diptera larvae, and crayfish (*Procambarus* spp.) (Nesbitt 1988).

A seasonal response to food availability on the Kissimmee Prairie is most apparent in use of oak hammocks and croplands. During the late summer and early fall, radio-tagged adult cranes with oak hammocks within their home range area fed on live oak (*Quercus virginia*) acorns. During this time, radio-tagged subadult cranes were found in recently harvested corn fields near the St. Johns River. From November through March, cranes reponded to the availability of supplemental feed in the form of corn, Japanese millet (*Echinochloa crus-galli*), and commercially prepared mixed grains on and around bull feeders, and on food plots intended for quail, turkey (*Meleagris gallopavo*) and Florida white-tailed deer (*Odocoileus virginianus osceola*).

Cranes in north Florida tend to forage in similar habitats to cranes on the Kissimmee Prairie; that is, primarily in improved pasture, herbaceous emergent wetlands, and the edge interface between these 2 habitats. The minimum convex home range for adult pairs and families on the Kissimmee Prairie, however, was much larger than for resident Florida sandhills (cranes who never left their territory) in north Florida ($\bar{x}$ = 6.57 km^2 versus $\bar{x}$ = 4.8 km^2) and smaller than the home range for itinerant north Florida cranes (cranes that left their territories after the breeding season) (Nesbitt 1988).

In contrast to Florida sandhill cranes on the Kissimmee Prairie, cranes in Okefenokee Swamp exclusively use wetland cover types (herbaceous, macrophyte, and scrub-shrub prairie) year-round for foraging. Bennett and Bennett (1987) reported a much smaller minimum convex annual home range for resident Florida sandhill cranes in

Okefenokee Swamp than for the Kissimmee Prairie. Annual home range averaged 1.05 km^2 $\pm$ 0.26 km^2 (SD) for 11 pairs, approximately 1/6 the size of the average home range on the Kissimmee Prairie. This difference in home range most likely reflects a rich year-round abundance of food sources in the Okefenokee wetland habitats.

In addition to food abundance and distribution, home range size and use also are determined by habitat composition, physiographic makeup, and other factors that fulfill survival needs (Laundre and Keller 1984). Habitat composition on the private ranchlands on the Kissimmee Prairie is characterized by what Poole (1974) terms as an aggregrated pattern. Large heterogenous expanses of improved pastures and herbaceous emergent wetlands are interspersed with stands of pine flatwoods and/or wooded wetlands, in particular cypress strands and domes. The aggregrated habitat dispersion results in a larger home range size than would be expected if the habitat was solely herbaceous emergent wetlands and improved pastures. This is because the cranes can avoid pine flatwoods and wooded wetlands by flying relatively short distances to suitable open habitats.

The interaction of habitat composition with predator avoidance and detection also influences home range size and use. In the case of Florida sandhill cranes, suitable roost sites in the form of relatively open herbaceous emergent wetlands with shallow water are necessary for nocturnal predator detection and avoidance. The pronounced wet and dry season on the Kissimmee Prairie, however, produces a seasonality in the availability of roost sites within a home range.

Predator avoidance and detection also influence the choice of foraging, nesting, and brooding habitat. In Florida and Okefenokee

Swamp, bobcats (Lynx rufus), red fox (Vulpes fulva), gray fox (Urocyon cinereoargenteus, feral hog (Sus scrofa), bald eagles (Haliaeetus leucocephalus), barred owls (Strix varia), and great horned owls (Bubo virginianus) are potential predators of prefledged or fledged cranes (Bennett 1978, Bennett and Bennett 1987, Walkinshaw 1987, Nesbitt 1988, this study). In this study, all radio-tagged cranes avoided pine flatwoods and wooded wetlands (shrub-scrub and cypress swamps and domes), even though these habitats were available throughout the area. Instead, cranes preferred open uplands and herbaceous emergent wetlands where predator detection was greater.

During the breeding season, cover for nesting and brooding prefledged chicks, as well as an increased territorial behavior influenced home range size and use. All radio-tagged breeding cranes had significantly smaller home ranges during the breeding season compared to the rest of the year, and tended to concentrate their activities on and near the nest pond. Although territorial behavior was observed during this time, the relatively high densities of breeding pairs in proximity to 3 of the 4 monitored breeding pairs may indicate that defense of an area, i.e. Noble's (1939) concept of territoriality, may be energetically beneficial for only very small areas.

While movements during the nesting and brooding period were more localized in the vicinity of the nest for the monitored cranes, in the case of AF3 and its prefledged chick, a loss of cover in the form of water caused a long distance movement out of the normal home range to a wetland with water. Long distance movements with prefledged chicks associated with food resources have been documented for Florida sandhill cranes in Okefenokee Swamp (Bennett and Bennett 1987), and for greater sandhill cranes in Seney National Wildlife Refuge (McMillen 1987), but not specifically for nocturnal roosting.

Social organization and behavior also will influence home range size. Florida sandhill crane subadults, for example, are typically transient and do not maintain the traditional idea of a home range - that is, a relatively fixed area (Bennett and Bennett 1987, Nesbitt 1988, this study). Breeding pairs, on the other hand, tend to stay in a relatively fixed area that includes a nest site, foraging areas, and roost ponds, and will defend portions of the home range.

For cranes, social tolerance of flocking permits all age classes to exploit food concentrations and roost together. Aside from the survival benefits that flocking offers (e.g. increased predator detection and foraging opportunities), its ultimate influence on home range for breeding cranes is threefold. Home range size tends to be larger, and temporal overlap between home ranges occurs more often. Use patterns also are much different than what would result if the paired cranes and families were strictly territorial. In the case of 4 of the 5 radio-tagged families and pairs, both temporary home range expansion and home range overlap were observed around food concentrations and when roost sites were limiting.

Habitat Selection

Chi-square analysis of diurnal habitat use revealed that paired-adults and families preferred herbaceous emergent wetlands within their annual home range. This preference for herbaceous emergent wetlands reflects not only the possible rich food resources available, but also their use as midday loafing and drinking sites, and as a source of cover that the upland habitats do not offer.

Interpreting habitat preference within a home range, however, can be misleading for 2 reasons. First, the analysis is for an area that the animal has already selected, while at the same time it does not deal with habitat characteristics such as interpersion and juxtaposition of vegetation (Johnson 1980, Porter and Church 1987). By defining as available habitat only those habitats within the annual modified minimum convex home range, the pronounced avoidance of pine flatwoods, wooded wetlands, and dry prairie is not detected because these habitats occur in such small quantities within the home range polygons.

Social Behavior

Florida sandhill cranes exhibiting subadult behavior were rarely observed alone, and tended to flock in groups of >2 cranes year-round. In addition to predator detection and increased foraging efficiency, suggested adaptive advantages to flocking by subadults include minimization of aggression initiated by adult-pairs in the area and mate selection (Moriarty 1976, Bishop 1984). Bishop (1984) found that pair formation in whooping cranes occurred in flocks composed primarily of nonbreeding cranes, including sexually immature subadults, and mature, unpaired adult cranes. Pairs formed between dyads that exhibited high frequencies of association over 1-3 winter seasons.

The year-round flocking behavior of Florida sandhill crane pairs and families in central Florida appears to be stimulated by 2 resources: food concentrations and suitable roost sites. The availability of both of these resources varies seasonally. Increased flocking beginning in summer and throughout the winter on croplands and at bull feeders is a response to planting practices and increased supplemental feed for wildlife. Drought situations occur often, especially towards the end of the dry season (May and June), and force families and pairs to flock due to a lack of alternative suitable roost sites.

Support for the idea of habitat-induced sociality on the Kissimmee Prairie comes from the Okefenokee Swamp where territories are defended by families throughout the year. Bennett and Bennett (in press) noted that during 3 of 4 seasons, no Okefenokee Swamp crane families were observed in flocks, and only 2.9% were observed in flocks during the December-February months. Among paired adult cranes, flocking was highest during September-November (16.6%) and no flocking was observed during the winter (December-February), despite the presence of migratory greater sandhill cranes. They attributed the solitary behavior of the Okefenokee cranes to the relatively even distribution of wetland food resources.

CHAPTER V
CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Florida Sandhill Crane in Central Florida

Nest initiation for the Florida sandhill crane in central Florida begins late in December and ends approximately May 20. Cranes in this area nest in both semi-permanent and seasonal palustrine emergent wetlands. Both the timing and the length of the breeding season for a given year depend on the wetland habitat conditions. During drought conditions, many cranes will forego nesting, whereas during years of suitable water levels in wetlands, unsuccessful breeders may renest at least once. Cranes nesting in ditched wetlands may experience a limited breeding season, due to a shortened hydroperiod.

Crude densities and population estimates for 1986 indicated that all 3 areas supported sizeable populations of Florida sandhill cranes: 0.52 pairs/km^2 on the Webb WMA, 0.25 pairs/km^2 on the Kissimmee Prairie, and 0.22 pairs/km^2 on Myakka River SP. For all 3 areas, overall juvenile recruitment rates were lowest following drought conditions (6.0-11.2 juveniles/100 adults). The mean juvenile recruitment rate for all areas for 1984-1986 was 11.0 juveniles/100 adults. While mortality rates of these birds are not available, juvenile recruitment rates indicate that the population is at least stable.

Using the modified-minimum area method, annual home ranges on the Kissimmee Prairie averaged 1.83 $\pm$ 1.03 km^2 (SD) for 6 radio-tagged paired adults and families, and 17.68 $\pm$ 19.01 km^2 for 3 subadults. Subadults did not maintain a consistent home range area throughout the year. Long distance moves (>5 km) usually were followed by temporary 1 to 4 months residence in an area.

Within the home range of the pairs and families, habitat use included primarily 3 types: improved pasture, herbaceous wetlands (palustrine emergent), and plowed or crop fields, including food plots. Although pine flatwoods, cypress strands, and dry prairie were in the immediate vicinity, cranes tended not to use these areas. Within their home range, Florida sandhill cranes tended to use herbaceous wetlands in a greater proportion than their availability. While cranes roosted exclusively in herbaceous wetlands, during the day they used wetlands for foraging and loafing.

All social classes of cranes were observed in flocks. Subadults were almost exclusively observed in flocks of >2 cranes. Flocking by breeding pairs and families was observed throughout the year and was associated with drought conditions and food concentrations.

Monitoring Florida Sandhill Crane Population

Systematic fixed-strip aerial surveys for nesting Florida sandhill cranes offer the most effective and cost efficient way to monitor crane populations in central Florida. Although the estimates are probably conservatively biased, and not precise, surveys can answer a broad range of ecological and management questions, including information on distribution and habitat preference. At the same time, because the methodology is standardized, results can be used for comparisons over time and between areas.

Potential for the Reintroduction of Whooping Cranes

At this time, all 3 areas could support the reintroduction of whooping cranes. There are sufficient public lands and suitable habitat available. Of the 3 areas, Myakka River SP and Webb WMA face increasing development pressures on and around their boundaries.

The Kissimmee Prairie, on the other hand, has maintained its rural character. This is due to both its relative isolation from major population centers and the presence of large public and private landholdings. The proposed first priority release site, Three Lakes WMA and Prairie-Lakes State Preserve includes 22,300 ha of public lands. The second priority release site, National Audubon Society Ordway-Whittell Kissimmee Prairie Sanctuary includes approximately 3,000 ha. Both areas are managed for wildlife values and maintenance of natural habitat conditions. At the same time, the surrounding land use for both sites is large cattle ranches that often manage for wildlife. In addition to the proposed Kissimmee Prairie release sites, there are an additional 82,500 ha of publicly-owned property in the surrounding areas. These public lands and the surrounding large, private landholding provide optimum conditions for the expansion of a whooping crane population.

Recommendations

In March 1988, the U.S. Whooping Crane Recovery Team recommended to the U.S. Fish and Wildlife Service that the Kissimmee Prairie, Florida and the Okefenokee Swamp, Florida be considered as potential release sites for a nonmigratory flock of whooping cranes. Based on my previous recommendations to the U.S. Whooping Crane Recovery Team, the proposed potential Myakka River State Park and the Webb WMA were excluded from further consideration. A final decision on the location for the proposed reintroduction of whooping cranes should be forthcoming in Fall 1989.

In light of both the decision regarding future whooping crane reintroduction, and the continued need to preserve and maintain habitat for the Florida sandhill cranes in central Florida, I recommend the following:

1. On the Kissimmee Prairie, Three Lakes Wildlife Management Area and Prairie-Lakes State Preserve should be given first priority as a reintroduction site, and the National Audubon Society Ordway-Whittell Kissimmee Prairie Sanctuary second priority.
2. As an index of the quality of crane habitat, Florida sandhill crane production on the Kissimmee Prairie should continue to be monitored at least every other year using aerial surveys.
    a. Surveys should be bi-weekly from mid-January to mid-May.
    b. Helicopters are preferable to fixed-wing aircraft.
3. On the Kissimmee Prairie, subadult movements should be studied in greater detail.

4. When a final decision has been made on the location of the whooping crane reintroduction site, the ongoing management of the selected site should be reviewed and prioritized with crane reintroduction in mind.
   a. No new public access roads should be built. Present public access should be reviewed with the possibility of restricting public access permanently for some areas, and during the nesting and brood-rearing season for other areas.
   b. Hydrological management aimed at recreating natural conditions should be given top priority and appropriate funding should be made available.
5. On all 3 areas undeveloped private lands adjoining the proposed reintroduction sites should be maintained as buffer zones either through outright acquisition, or through the purchase of perpetual conservation easements.
   a. The proposed C.A.R.L. addition to Three Lakes WMA/Prairie-Lakes State Preserve should be acquired or otherwise protected.
   b. Sarasota County should purchase the remaining privately-owned portion of the original Ringling-MacArthur tract.
   c. The Hall Ranch should be purchased for the Webb WMA.
6. Large, private ranches in the vicinity of the study areas should be given incentives to maintain their properties as open space.
7. Existing electrical transmission lines on all 3 areas should be made as safe as possible for cranes in areas frequently

used by them. Siting of any new transmission lines should take into account any large populations of cranes.

APPENDIX A
MAP OF WEBB WILDLIFE MANAGEMENT AREA

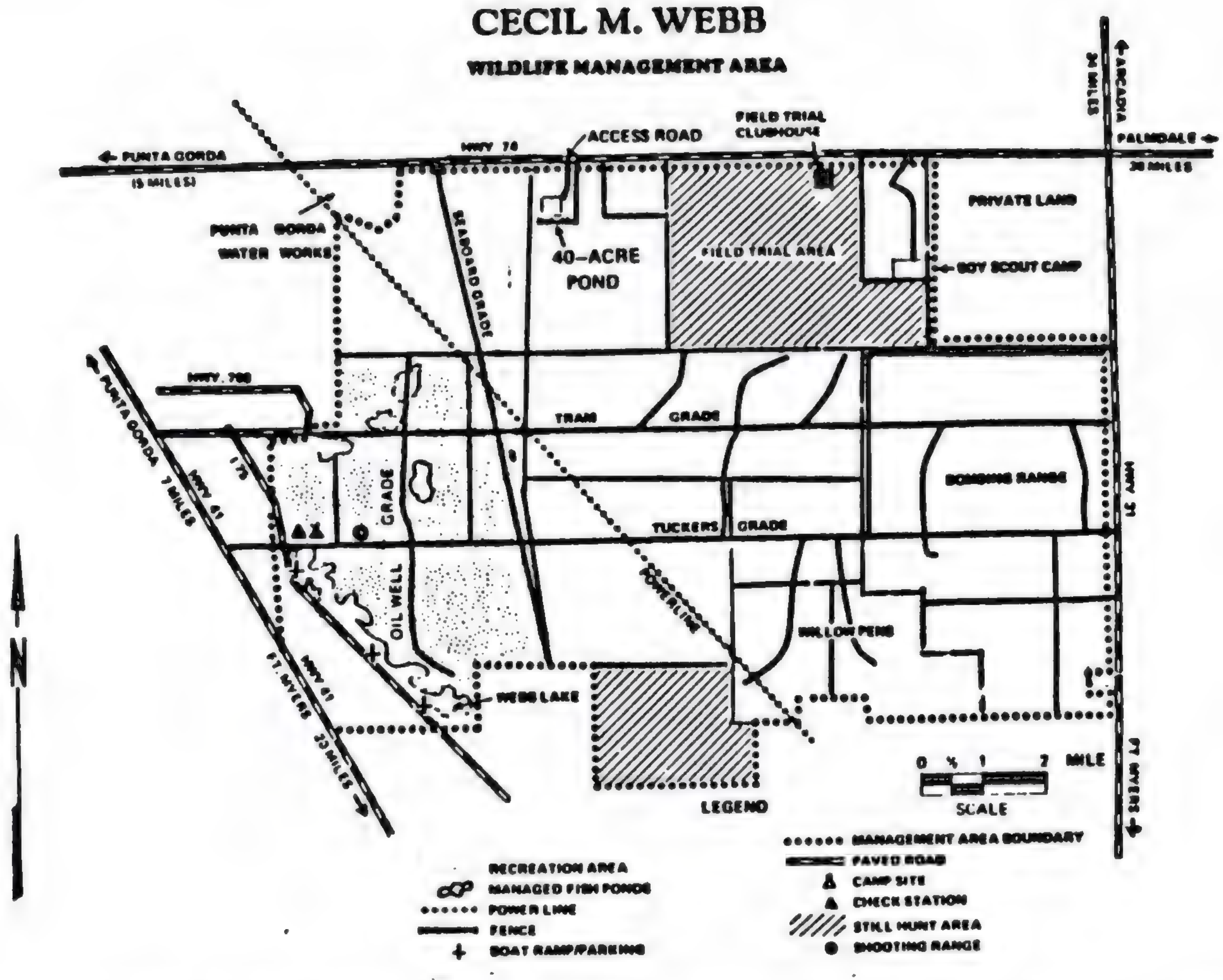

Figure A-1. Map of Webb Wildlife Management Area (from: Florida Game and Fresh Water Fish Commission leaflet 1987, with additions).

APPENDIX B
MAPS OF THREE LAKES WILDLIFE MANAGEMENT AREA AND PROPOSED THREE LAKES WMA/PRAIRIE-LAKES STATE PRESERVE ADDITION

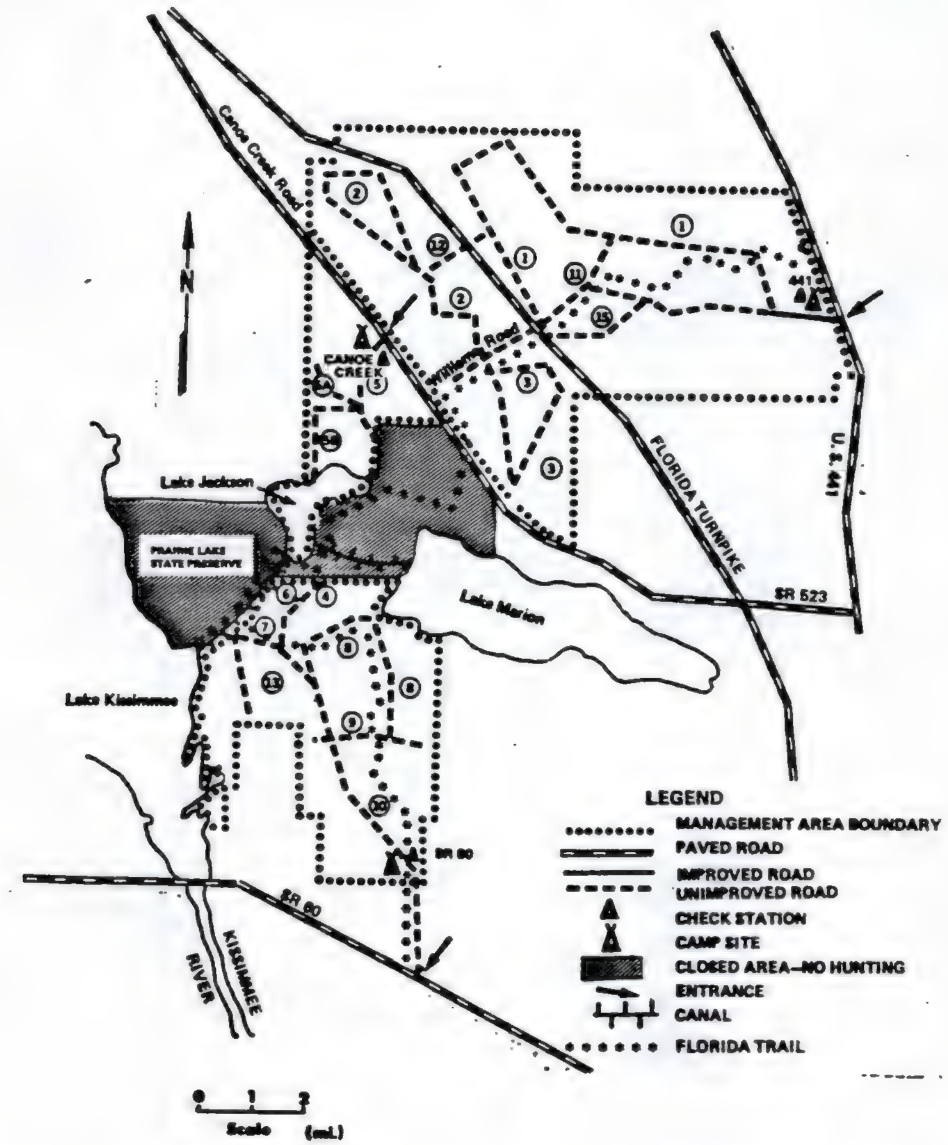

Figure B-1. Map of Three Lakes Wildlife Management Area (from: Florida Game and Fresh Water Fish Commission leaflet 1987, with additions).

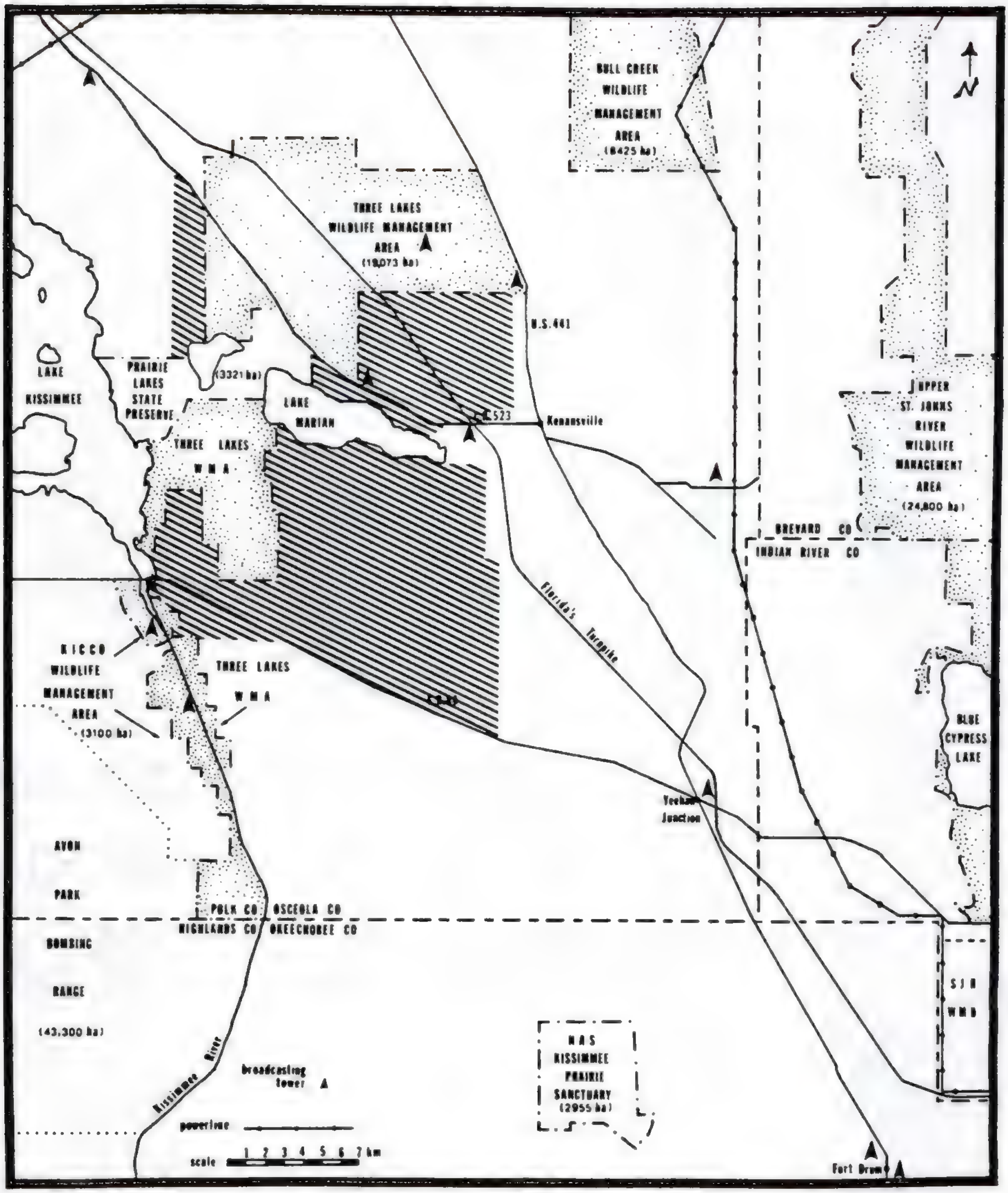

Figure B-2. Map of proposed Three Lakes WMA/Prairie-Lakes State Preserve addition.

APPENDIX C
LOCATION AND OWNERSHIP OF NEST WETLANDS ON 3 SITES IN CENTRAL FLORIDA

Table C-1. Ownership and location (township, range, section, and quarter section) of nests and flightless chicks located during 1985 and 1986 on and around Myakka River State Park study area. Nests located by local informants are noted by initials.

#	Owner	Co[a]	TS	RE	Se	Qu	Day	Mo	Yr	Met	N/Ch	Who
1985												
1	Longino Ranch	S	38	22	21	SW	11	3	85	air	nest	
2	Henry Ranch Feed	S	38	19	26	NW	19	3	85	air	nest	
3	Myakka River SP	S	38	20	6	NE	25	3	85	grd	nest	HJ
4	Myakka River SP	S	37	20	15	C	5	4	85	air	chicks	
5	Myakka River SP	S	37	20	12	CS	19	3	85	air	nest	
6	R. Garber	M	37	22	31	CE	5	4	85	air	nest	
7	North Port	S	39	21	4	NE	8	4	85	air	nest	
8	L. & V. Hawkins	S	37	19	25	SE	8	4	85	air	nest	
9	Longino Ranch	S	38	22	21	SW	8	4	85	air	nest	
10	A. Schrader	M	37	21	2	SW	17	4	85	air	nest	
11	Myakka River SP	M	37	21	26	SE	17	4	85	air	nest	
12	MCK Farms	S	39	22	5	NW	17	4	85	air	nest	
13	Sarasota Co.	S	38	21	29	CS	24	4	85	grd	nest	HJ
14	Myakka River SP	M	37	21	30	NW	29	4	85	air	nest	
15	M. Carlton & Sons	S	38	22	6	SW	29	4	85	air	nest	
1986												
1	Sarasota Co.	S	38	20	26		15	1	86	air	nest	
2	Mag Prop., Inc.	S	36	20	25	NW	29	1	86	air	nest	
3	W. Gauldin	S	36	19	15[b]		29	1	86	air	nest	
4	1st Natl Bank Tampa	M	37	22	5	NE	30	1	86	air	nest	
5	Hi-Hat Ranch	S	37	19	12	NW	29	1	86	air	nest	
6	Hi Hat Ranch	S	37	19	24	NE	29	1	86	air	nest	
7	L. & V. Hawkins	S	37	19	25	NW	29	1	86	air	nest	
8	G.L. Green	S	38	19	23	SW	29	1	86	air	nest	
9	Sarasota Co.	S	38	21	32	SW	29	1	86	air	nest	
10	L.H. Hawkins	S	37	19	25	SE	12	2	86	air	nest	
11	J. Walton	S	38	22	32	SE	26	2	86	air	nest	
12	Longino Ranch	S	38	22	24	SW	26	2	86	air	nest	
13	A.H. Horton	M	37	21	16	SW	26	2	86	air	nest	
14	M. Carlton & Sons	S	38	22	17	NW	12	3	86	air	nest	

Table C-1--continued.

#	Owner	Co	TS	RE	Se	Qu	Dy	Mo	Yr	Met	N/Ch	Who
15	MacArthur Fdtn.	S	38	20	13	NW	25	2	86	air	nest	
16	MacArthur Fdtn.	S	38	20	1	NE	12	3	86	air	nest	
17	Myakka River SP	S	37	20	15	SE	10	3	86	grd	chicks	RD
18	G. Clavel	D	38	23	30	NW	26	3	86	air	nest	
19	C. Daughtry	S	38	22	12	SE	26	3	86	air	nest	
20	L. & V. Hawkins	S	37	19	35	NW	26	3	86	air	nest	
21	L. & V. Hawkins	S	37	19	25	C	12	2	86	air	nest	
22	L. & V. Hawkins	S	37	19	25	NW	12	3	86	air	nest	
23	R. Mason	M	37	21	14	NE	26	3	86	air	nest	
24	J. & M. Murphy	M	36	21	30	SE	26	3	86	air	nest	
25	Hi-Hat Ranch	S	36	19	23	NW	12	4	86	air	nest	
26	Hi-Hat Ranch	S	36	20	22	NW	12	4	86	air	nest	
27	Hi-Hat Ranch	S	36	20	32	NE	12	4	86	air	nest	
28	Myakka River SP	S	37	20	2	SW	12	4	86	air	nest	
29	R. Mason	M	37	21	14	NE	12	4	86	air	nest	
30	Myakka River SP	M	37	21	25	NW	12	4	86	air	nest	
31	D. & V. Tueton	M	37	22	30	NE	12	4	86	air	nest	
32	M. Carlton & Sons	S	38	21	1	NW	12	4	86	air	nest	
33	L. & V. Hawkins	S	38	19	2	NE	12	4	86	air	nest	
34	M. Carlton & Sons	S	38	22	18	SW	12	4	86	air	nest	
35	Longino Ranch	S	38	22	27	NW	12	4	86	air	nest	
36	Henry Ranch Feed	S	38	19	26	NW	12	4	86	air	nest	
37	Fla. Power Light	S	38	19	35	NE	12	4	86	air	nest	
38	S.T. Dean	S	38	19	35	NW	12	4	86	air	nest	
39	Newman	S	36	20	17	SW	22	4	86	air	nest	
40	Hi-Hat Ranch	S	36	20	30	SE	22	4	86	air	nest	
41	Hi-Hat Ranch	S	37	20	7	NW	22	4	86	air	nest	
42	A. Schrader	M	37	21	3	NE	22	4	86	air	nest	
43	C. Schmidt	S	37	20	16	SE	22	4	86	air	nest	
44	R. Mason	M	37	21	14	NE	8	5	86	air	nest	
45	Myakka River SP	S	37	20	21	NE	3	6	86	grd	chicks	RD
46	Myakka River SP	M	37	21	18	C	3	6	86	grd	chicks	RD

[a] Letters denote county: S=Sarasota, M=Manatee, D=DeSoto.
[b] Approximate location, not confirmed.

Table C-2. Ownership and location (township, range, section, and quarter section) and day of first sighting of nests or flightless chicks located during 1985 on and around Kissimmee Prairie study area. Nests located by local informants are noted by initials.

#	Owner	Co[a]	TS	RE	Se	Qu	Day	Mo	Yr	Met	N/C	Who
1985												
1	Bass Ranch	OS	31	34	30	SW	23	2	85	grd	nest	LW
2	Bass Ranch	OS	32	34	5	W	18	2	85	air	nest	
3	Bass Ranch	OS	32	34	5	W	18	2	85	air	nest	
4	Hayman 711 Ranch	OS	31	34	5	CW	3	3	85	grd	nest	
5	Hayman 711 Ranch	OS	31	34	5	SW	2	3	85	grd	nest	LW
6	Bass Ranch	OS	31	33	34	SW	1	3	85	grd	nest	LW
7	Bass Ranch	OS	31	33	35	SW	14	3	85	air	nest	
8	Kobblegard	OS	33	34	5	NE	14	3	85	air	nest	
9	Latt Maxcy Ranch	OS	32	32	5		14	3	85	air	nest	
10	Slash S Cattle	OS	31	34	18	CN	16	3	85	air	nest	
11	Hayman 711 Ranch	OS	31	34	5	CW	16	3	85	air	nest	
12	Escape Ranch	OS	30	34	20	NW	4	3	85	air	nest	
13	Bass Ranch	OS	32	34	5	CN	16	3	85	air	chicks	
14	Bass Ranch	OS	32	33	1	NE	16	3	85	air	nest	
15	Latt Maxcy Ranch	OS	32	34	29	SE	16	3	85	air	nest	
16	State Florida	OS	30	31	15	C	20	3	85	air	nest	
17	Hayman 711 Ranch	OS	30	33	34	SE	21	3	85	grd	nest	BH
18	Rollins Ranch	OS	32	34	1	NW	14	3	85	air	nest	
19	Mills Ranch	OS	31	34	11	NW	9	4	85	air	nest	
20	L. Owens	OK	33	34	36	CN	9	4	85	air	nest	
21	Latt Maxcy Ranch	OS	32	34	31	SW	24	4	85	air	nest	
22	Powell/Oliver	OK	34	34	12	NE	24	4	85	air	nest	
23	H. Thomas	OK	34	33	1	SW	1	4	85	grd	nest	RC
24	H. Thomas	OK	34	33	1	SW	1	4	85	grd	chicks	
25	D. Carlton	OK	33	34	3	SW	12	4	85	grd	nest	RC
26	Lucky L Ranch	OS	30	33	16	SE	19	4	85	grd	nest	
27	Adams Ranch	OS	31	33	4	NE	21	4	85	grd	nest	TH
28	Adams Ranch	OS	30	33	20		14	3	85	grd	chicks	
29	D. Carlton	OK	33	34	35		29	1	85	air	nest	
30	Hayman 711 Ranch	OS	30	33	25		9	3	85	grd	chicks	MR
31	Adams Ranch	OK	33	35	18		5	3	85	grd	chicks	TH
32	Adams Ranch	OK	33	34	8		4	3	85	air	nest	
33	Rogers 7Lazy11	OS	31	34	13		9	4	85	air	nest	
34	Mills Ranch	OS	31	34	3	SE	2	6	85	grd	chicks	
35	Rollins Ranch	IR	31	35	25	SW	9	5	85	grd	nest	JO
36	Escape Ranch	OS	30	34	28		15	5	85	grd	chick	
37	Bronsons	OS	30	34	18		17	5	85	grd	chicks	
38	J. Barnett	OS	30	32	3		23	5	85	grd	chicks	
39	J. Overstreet Ranch	OS	29	31	28		28	5	85	grd	chicks	

Table C-2.---continued.

#	Owner	Co	TS	RE	Se	Qu	Day	Mo	Yr	Met	N/C	Who
1986												
1	Rollins Ranch	OS	32	34	1	NW	21	1	86	air	nest	
2	Latt Maxcy Ranch	OK	33	33	33	SE	21	1	86	air	nest	
3	Bronsons	OS	29	31	8	SW	4	2	86	air	nest	
4	Bronsons	OS	29	31	11	SW	4	2	86	air	nest	
5	Escape Ranch	OS	30	34	19	NW	4	2	86	air	nest	
6	Crosby	OS	30	33	24	NE	4	2	86	air	nest	
7	Bass Ranch	OS	32	34	5	NW	4	2	86	air	nest	
8	Powell/Oliver	OK	34	34	12	NE	4	2	86	air	nest	
9	Mills Ranch	OS	31	34	3	SE	4	2	86	air	nest	
10	Latt Maxcy Ranch	OS	32	34	33	SW	5	2	86	air	nest	
11	Latt Maxcy Ranch	OS	32	34	33	SE	5	2	86	air	nest	
12	P. Whaley	OS	28	31	7	N	5	2	86	air	nest	
13	Bronsons	OS	27	30	35	SE	5	2	86	air	nest	
14	Bronsons	OS	29	31	21	NW	5	2	86	air	nest	
15	J. Hancock Ins.Co.	OS	30	31	25	C	5	2	86	air	nest	
16	Adams Ranch	OS	30	33	29	NW	15	2	86	grd	chicks	
17	Adams Ranch	OS	30	33	29	C	15	2	86	grd	nest	
18	Adams Ranch	OS	30	32	25	SE	15	2	86	grd	nest	
19	L.J. Harvey	OS	30	33	11		3	2	86	grd	nest	LH
20	J. Barnett	OS	30	32	2	SE	16	2	86	grd	nest	
21	Bronsons	OS	29	31	14	SW	16	2	86	grd	nest	
22	Bronsons	OS	28	31	19	NE	16	2	86	grd	nest	
23	Wedgeworth Farms	OS	31	34	27	NE	17	2	86	air	nest	
24	Powell/Oliver	OK	34	34	11	NW	17	2	86	air	nest	
25	D. Carlton	OK	34	34	9	NW	17	2	86	air	nest	
26	D. Carlton	OK	33	34	33	NE	17	2	86	air	nest	
27	D. Carlton	OK	33	34	34	NE	17	2	86	air	nest	
28	H. Keats	OK	33	34	36	SW	17	2	86	air	nest	
29	Latt Maxcy Ranch	OK	33	33	10	NW	17	2	86	air	nest	
30	Latt Maxcy Ranch	OK	33	33	10	SE	17	2	86	air	nest	
31	Adams Ranch	OK	33	34	7	NE	17	2	86	air	nest	
32	Kobblegard	OK	33	34	5	NE	17	2	86	air	nest	
33	Latt Maxcy Ranch	OS	32	34	31	SW	17	2	86	air	nest	
34	Latt Maxcy Ranch	OS	32	34	17	NE	17	2	86	air	nest	
35	Latt Maxcy Ranch	OS	32	32	1	SE	17	2	86	air	nest	
36	Rogers 7Lazy11	OS	31	34	1	SW	5	3	86	grd	chick	
37	Escape Ranch	OS	30	34	33	N	17	2	86	air	nest	
38	Escape Ranch	OS	30	34	32	NE	17	2	86	air	nest	
39	Bronsons	OS	30	34	23	NE	17	2	86	air	nest	
40	Bronsons	OS	30	34	21	SW	17	2	86	air	nest	
41	Three Lakes WMA	OS	30	32	19	SW	17	2	86	air	nest	
42	R. Overstreet Ranch	OS	29	31	35	SW	17	2	86	air	nest	
43	Bronsons	OS	29	31	9	SW	17	2	86	air	nest	
44	Three Lakes WMA	OS	29	32	17	NE	17	2	86	air	nest	
45	Three Lakes WMA	OS	29	32	6	SE	17	2	86	air	nest	
46	Adams Ranch	OS	30	32	25	SW	24	2	86	grd	nest	

Table C-2.---continued.

#	Owner	Co	TS	RE	Se	Qu	Day	Mo	Yr	Met	N/C	Who
47	Adams Ranch	OS	30	33	31	SE	2	3	86	grd	nest	
48	R. Overstreet Ranch	OS	29	31	23	SE	3	3	86	air	nest	
49	Bass Ranch	OS	31	33	33	SW	18	2	86	grd	nest	LW
50	R. Overstreet Ranch	OS	29	31	36	NW	3	3	86	air	nest	
51	Prairie-Lakes Reserv	OS	30	31	11	C	3	3	86	air	nest	
52	Hayman 711 Ranch	OS	30	34	31	NW	3	3	86	air	nest	
53	Three Lakes WMA	OS	31	32	5	SW	3	3	86	air	nest	
54	Bass Ranch	OS	31	33	35	NW	3	3	86	air	nest	
55	Bass Ranch	OS	31	34	30	SW	18	2	86	grd	nest	LW
56	Latt Maxcy Ranch	OS	32	33	6	SW	3	3	86	air	nest	
57	Latt Maxcy Ranch	OS	32	32	5	SE	3	3	86	air	nest	
58	Latt Maxcy Ranch	OS	32	34	16	SW	3	3	86	air	nest	
59	Latt Maxcy Ranch	OS	32	33	26	NW	3	3	86	air	nest	
60	Latt Maxcy Ranch	OS	32	33	30	NE	3	3	86	air	nest	
61	Latt Maxcy Ranch	OS	32	33	33	SW	3	3	86	air	nest	
62	D. Carlton	OK	33	34	34	S	3	3	86	air	nest	
63	Natl. Audubon Soc.	OK	33	33	36	NE	3	3	86	air	nest	
64	Mills Ranch	OS	31	34	11	NW	7	3	86	grd	nest	
65	Adams Ranch	OS	30	32	25	SE	17	3	86	grd	chicks	
66	Mills Ranch	OS	31	34	3	NE	18	3	86	grd	nest	
67	T-Pee Beefmasters	OS	30	33	13	C	18	3	86	grd	chicks	
68	Bass Ranch	OS	32	34	6	NW	24	2	86	grd	nest	LW
69	Adams Ranch	OS	31	33	3	SW	24	2	86	grd	nest	LW
70	Latt Maxcy Ranch	OS	32	34	36	NW	12	3	86	grd	chicks	GW
71	B. Geiger	OS	32	34	3	NE	21	3	86	grd	chicks	
72	Mills Ranch	OS	31	34	3	SE	24	3	86	air	nest	
73	Mills Ranch	OS	31	34	10	NE	24	3	86	air	nest	
74	Rogers 7Lazy11	OS	31	34	2	CE	24	3	86	air	nest	
79	R. Overstreet Ranch	OS	29	31	33	S	4	3	86	air	nest	
80	Three Lakes WMA	OS	29	32	19	SW	24	3	86	air	nest	
82	T. Gannarelli	OS	29	31	7	NE	24	3	86	air	nest	
83	Bronsons	OS	29	31	10	NE	24	3	86	air	nest	
84	R. Overstreet Ranch	OS	29	31	24	NE	24	3	86	air	nest	
85	R. Overstreet Ranch	OS	29	31	25	SE	24	3	86	air	nest	
87	Three Lakes WMA	OS	30	31	26	N	24	3	86	air	nest	
88	Hayman 711 Ranch	OS	31	34	8	NE	28	3	86	grd	chicks	
89	Mills Ranch	OS	31	34	4	SE	26	3	86	grd	chick	BM
90	Mills Ranch	OS	31	34	3	SE	1	4	86	air	nest	
91	Mills Ranch	OS	31	34	3	C	1	4	86	air	nest	
93	Three Lakes WMA	OS	30	32	33	NE	1	4	86	air	nest	
94	Escape Ranch	OS	30	34	34	NW	1	4	86	air	nest	
95	Bronsons	OS	30	34	22	SW	1	4	86	air	nest	
96	Escape Ranch	OS	30	34	19	SE	1	4	86	air	nest	
97	Crosby	OS	30	33	24	SE	1	4	86	air	nest	
98	R. Overstreet Ranch	OS	29	31	22	SW	1	4	86	air	nest	
99	Bronsons	OS	29	31	14	NW	1	4	86	air	nest	
100	Bar Seven Ranch	OS	28	31	31	SE	1	4	86	air	nest	
101	Bronsons	OS	29	31	1	SW	1	4	86	air	nest	

Table C-2.---continued.

#	Owner	Co	TS	RE	Se	Qu	Day	Mo	Yr	Met	N/C	Who
102	Three Lakes WMA	OS	29	32	34	NE	1	4	86	air	nest	
103	J. Hancock Ins.Co.	OS	31	32	16	NE	4	4	86	grd	chicks	
104	Adams Ranch	OK	33	34	5	NE	2	4	86	air	chick	
105	Mills Ranch	OS	31	34	4	NW	5	4	86	grd	chick	
106	Latt Maxcy Ranch	OS	32	33	35	SW	2	4	86	air	chick	
107	Three Lakes WMA	OS	31	32	30	NW	15	4	86	air	nest	
108	Latt Maxcy Ranch	OS	32	32	2	NE	15	4	86	air	nest	
109		OK	34	32	11	NW	15	4	86	air	chick	
110	Latt Maxcy Ranch	OS	32	33	4	NE	8	4	86	grd	chicks	
111	Latt Maxcy Ranch	OS	32	33	10	SW	8	4	86	grd	chick	
112	Bass Ranch	OS	32	33	1	NW	10	4	86	grd	chicks	
113	Adams Ranch	OK	33	35	18	NE	15	4	86	grd	chicks	
114	Mills Ranch	OS	31	34	5	NW	16	4	86	grd	chicks	
115	Mills Ranch	OS	31	34	4	NW	16	4	86	grd	chicks	
116	R.Overstreet Ranch	OS	29	31	28	NW	17	4	86	grd	chicks	RO
117	Latt Maxcy Ranch	OS	32	33	36	NE	18	4	86	grd	chicks	
118	G. Harvey	OS	30	33	13	SW	18	4	86	grd	chicks	
119	Bass Ranch	OS	31	34	32	SW	21	3	86	grd	chick	RR
120	Rollins Ranch	OS	31	34	23	NE	2	4	86	air	nest	
121	Bronsons	OS	30	34	23	SE	19	4	86	grd	nest	
122	J.Hancock Ins.Co.	OS	28	31	26	SW	28	4	86	grd	chicks	
123	Three Lakes WMA	OS	29	32	10	SW	29	4	86	air	nest	
124	Escape Ranch	OS	30	34	20	NW	29	4	86	air	nest	
126	Adams Ranch	OS	31	33	4	NE	29	4	86	air	nest	
127	Hayman 711 Ranch	OS	31	33	2	SE	29	4	86	air	chick	
128	Rollins Ranch	IR	32	35	6	NW	29	4	86	air	nest	
129	D. Carlton	OK	34	34	9	NW	29	4	86	air	nest	
130	D. Carlton	OK	33	34	27	SE	1	5	86	grd	chick	
131	Latt Maxcy Ranch	OK	33	33	3	NE	29	4	86	air	nest	
132	Hayman 711 Ranch	OS	31	34	5	NW	5	5	86	grd	chick	
133	C. Griffis	OS	30	33	24	SW	10	5	86	grd	chicks	
134	L.J. Harvey	OS	30	33	14	SE	10	5	86	grd	chicks	
135	Latt Maxcy Ranch	OS	32	34	18	NE	15	5	86	air	nest	
136	Bass Ranch	OS	32	34	6	SW	20	5	86	grd	nest	
137	Escape Ranch	OS	30	34	26	SW	6	6	86	grd	chick	
138	R. McDowell	OS	30	33	11	SE	24	3	86	air	nest	
139	Bronsons	OS	30	34	9	W	24	3	86	air	nest	
140	Bronsons	OS	30	34	11	SW	24	3	86	air	nest	
141	River Ranch	P	31	31	15	NE	24	3	86	air	nest	
142	Rollins Ranch	IR	35	31	30		24	3	86	air	nest	
143	H. Thomas	OK	34	33	1	SE		5	86	grd	chicks	RC
144	Natl. Audubon Soc.	OK	33	33	24			3	86	grd	chick	RC
145	P. Whaley	OS	28	31	8	SE	18	4	86	grd	chicks	

[a] Letters denote county: OS=Osceola, OK=Okeechobee, P=Polk, IR=Indian River

Table C-3. Ownership and location (township, range, section, and quarter section) of nests and flightless chicks located during 1985 and 1986 on and around Webb Wildlife Management Area study area. Nests located by local informants are noted by initials.

#	Owner	Co[a]	TS	RE	Se	Qu	Day	Mo	Yr	Met	N/Ch	Who
1985												
1	Webb WMA	C	42	24	24	N[b]	11	3	85	air	nest	
2	Webb WMA	C	42	24	18	SW	19	3	85	air	nest	
3	M.L. Hall	C	41	25	12	CN	19	3	85	air	nest	
4	P&P Partnership	C	42	24	25	SW	5	4	85	air	nest	
5	Webb WMA	C	41	25	27	NW	8	4	85	air	nest	
1986												
1	M.L. Hall	C	41	25	2	SE	15	1	86	air	nest	
2	Webb WMA	C	41	24	15	SE	15	1	86	air	nest	
3	Webb WMA	C	41	24	17	CW	15	1	86	air	nest	
4	Webb WMA	C	42	23	1	NW	29	1	86	air	nest	
5	M.L. Hall	C	41	25	3	SW	29	1	86	air	nest	
6	Webb WMA	C	41	25	8	NW	29	1	86	air	nest	
7	M.L. Hall	C	41	25	13	NW	30	1	86	air	nest	
8	Webb WMA	C	41	25	18	SE	30	1	86	air	nest	
9	Webb WMA	C	41	24	15	SE	30	1	86	air	nest	
10	Webb WMA	C	42	25	7	SW	30	1	86	air	nest	
11	Webb WMA	C	42	25	15	NE	30	1	86	air	nest	
12	Multiple private	C	42	25	29	NW	30	1	86	air	nest	
13	1st Bank T.Boca Rtn	C	42	24	28	C	30	1	86	air	nest	
14	1st Bank T.Boca Rtn	C	42	24	29	NE	30	1	86	air	nest	
15	Multiple private	C	42	24	15	SE	12	2	86	air	nest	
16	Webb WMA	C	42	24	18	SW	12	2	86	air	nest	
17	Webb WMA	C	42	23	1	NW	12	2	86	air	nest	
18	Webb WMA	C	42	24	5	SW	12	2	86	air	nest	
19	Webb WMA	C	41	25	29	NE	12	2	86	air	nest	
20	Webb WMA	C	41	24	30	NE	12	2	86	air	nest	
21	Webb WMA	C	41	24	14	SE	12	2	86	air	nest	
22	Webb WMA	C	41	24	11	NE	12	2	86	air	nest	
23	Webb WMA	C	42	23	13	NE	26	2	86	air	nest	
24	Webb WMA	C	42	24	2	NE	26	2	86	air	nest	
25	Webb WMA	C	41	24	15	SW	26	2	86	air	nest	
26	P&P Partnership	C	42	24	25	SW	12	3	86	air	nest	
27	Babcock Ranch	C	42	26	17	NW	12	3	86	air	nest	
28	Webb WMA	C	41	25	18	NE	12	3	86	air	nest	
29	Webb WMA	C	42	24	18	NW	12	3	86	air	nest	
30	Webb WMA	C	41	25	6	SE	12	3	86	air	nest	
31	Webb WMA	C	42	25	1	CE	12	3	86	air	nest	
32	Webb WMA	C	41	25	28	SE	12	3	86	air	nest	
33	Webb WMA	C	41	24	30	SW	12	3	86	air	nest	
34	Webb WMA	C	41	24	9	NW	12	3	86	air	nest	
36	Webb WMA	C	41	25	25	SW	26	3	86	air	nest	

Table C-3--continued.

#	Owner	Co	TS	RE	Se	Qu	Dy	Mo	Yr	Met	N/Ch	Who
37	Babcock Ranch	C	42	26	15	NE	12	4	86	air	nest	
38	Webb WMA	C	42	24	18	NE	12	4	86	air	nest	
39	Charlotte County	C	41	23	14	SW	12	4	86	air	nest	
40	Webb WMA	C	41	23	25	NE	12	4	86	air	nest	
41	Babcock Ranch	C	41	26	7	SE	12	4	86	air	nest	
42	Webb WMA	C	41	24	1	SE	12	4	86	air	nest	
43	Webb WMA	C	41	24	32	SW	11	4	86	grd	nest	MK
44	Webb WMA	C	41	25	6	CN	3	2	86	grd	chick	HA
45	Webb WMA	C	41	25	26	SE	23	4	86	air	nest	
46	Webb WMA	C	42	25	15	NW	12	3	86	air	nest	
47	Webb WMA	C	42	24	17	NE	8	5	86	air	nest	
48	Webb WMA	C	42	23	1	NE	5	5	86	grd	nest	LC

[a] Letters denote county: C=Charlotte.
[b] Approximate location, not confirmed.

APPENDIX D
SPEARMAN RANK CORRELATION BETWEEN BREEDING DENSITIES AND ENVIRONMENTAL VARIABLES

Table D-1. Rho and *P*-values for Spearman rank correlations between densities of breeding Florida sandhill cranes detected from aerial surveys and environmental variables.

Variable	Rho	*P*-value
H^2O Level 14 Day $\bar{x}$	0.52188	0.0001
H^2O Level 30 Day $\bar{x}$	0.51755	0.0001
H^2O Level 7 Day $\bar{x}$	0.51215	0.0001
Sum Rain 30 Days	0.35488	0.0040
Temp Max 7 Day $\bar{x}$	-0.29593	0.0176
Dry/Rise 30 Day $\bar{x}$	0.25691	0.0404
Sum Rain 14 Days	0.21858	0.0827
Temp Max 14 Day $\bar{x}$	-0.19493	0.1227
Days Rain 30 Days	0.16327	0.1974
Dry/Rise 7 Day $\bar{x}$	-0.14803	0.2431
Days Rain 7 Days	-0.14268	0.2607
Temp Max 30 Day $\bar{x}$	-0.14115	0.2659
Temp Min 7 Day $\bar{x}$	-0.11475	0.3666
Dry/Rise 14 Day $\bar{x}$	-0.08697	0.4944
Temp Min 14 Day $\bar{x}$	-0.07243	0.5695
Julian Date	-0.04471	0.7257
Julian Date^2	-0.04471	0.7257
Days Rain 14 Days	0.04175	0.7433
Sum Rain 7 Days	0.01429	0.9108
Temp Min 30 Day $\bar{x}$	0.00734	0.9541

Table D-2. Rho and P-values for Spearman rank correlations between densities of breeding Florida sandhill cranes detected from aerial surveys and water levels preceding surveys. All correlations are significant $\underline{P} \leq 0.01$.

Days Before Flight	Rho	$\underline{P}$-Value
15	0.53239	0.0001
14	0.53071	0.0001
16	0.5187	0.0001
8	0.51732	0.0001
3	0.51425	0.0001
2	0.51376	0.0001
3	0.51341	0.0001
7	0.51146	0.0001
2	0.51135	0.0001
9	0.50889	0.0001
6	0.50658	0.0001
1	0.50354	0.0001
10	0.49916	0.0001
5	0.49907	0.0001
11	0.49723	0.0001
17	0.49618	0.0001
4	0.4944	0.0001
24	0.46555	0.0001
25	0.45501	0.0002
23	0.45481	0.0002
27	0.45344	0.0002
18	0.4513	0.0002
28	0.4468	0.0002
19	0.44451	0.0002
22	0.44415	0.0002
26	0.44383	0.0002
21	0.42963	0.0004
20	0.42756	0.0004
29	0.42606	0.0004
30	0.40189	0.001

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BIOGRAPHICAL SKETCH

Mary Anne Bishop was born 6 September 1952 at Berea, Ohio. She attended the University of Wisconsin-Madison and the Universidad Catolica, Escuela de Economia in Santiago, Chile for her undergraduate career. She graduated with a B.B.A. from the University of Wisconsin in August 1974.

Shortly thereafter she travelled again to Chile, this time to Vina del Mar, Chile, where she spent a year teaching English. Upon her return she moved to Texas, where she spent the next 8 years. Following an uninteresting job as a housing counselor, she moved into a new career as a zookeeper at the San Antonio Zoological Gardens in San Antonio, Texas. After 3 1/2 happy years (1977-1980) in the bird and large mammal departments, she decided to flee the cage.

She began a study on subadult whooping cranes at Aransas National Wildlife Refuge, Texas in fall 1980 under the sponsorship of the National Audubon Society. The following year she entered the graduate program in the Department of Wildlife and Fisheries Sciences, Texas A & M University, and graduated with a M.S. in August 1984. She moved to Florida in fall 1983 to continue her interest in cranes as a doctoral student at the University of Florida. She is glad to be finished with her degree and is not quite sure what her future address will be.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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